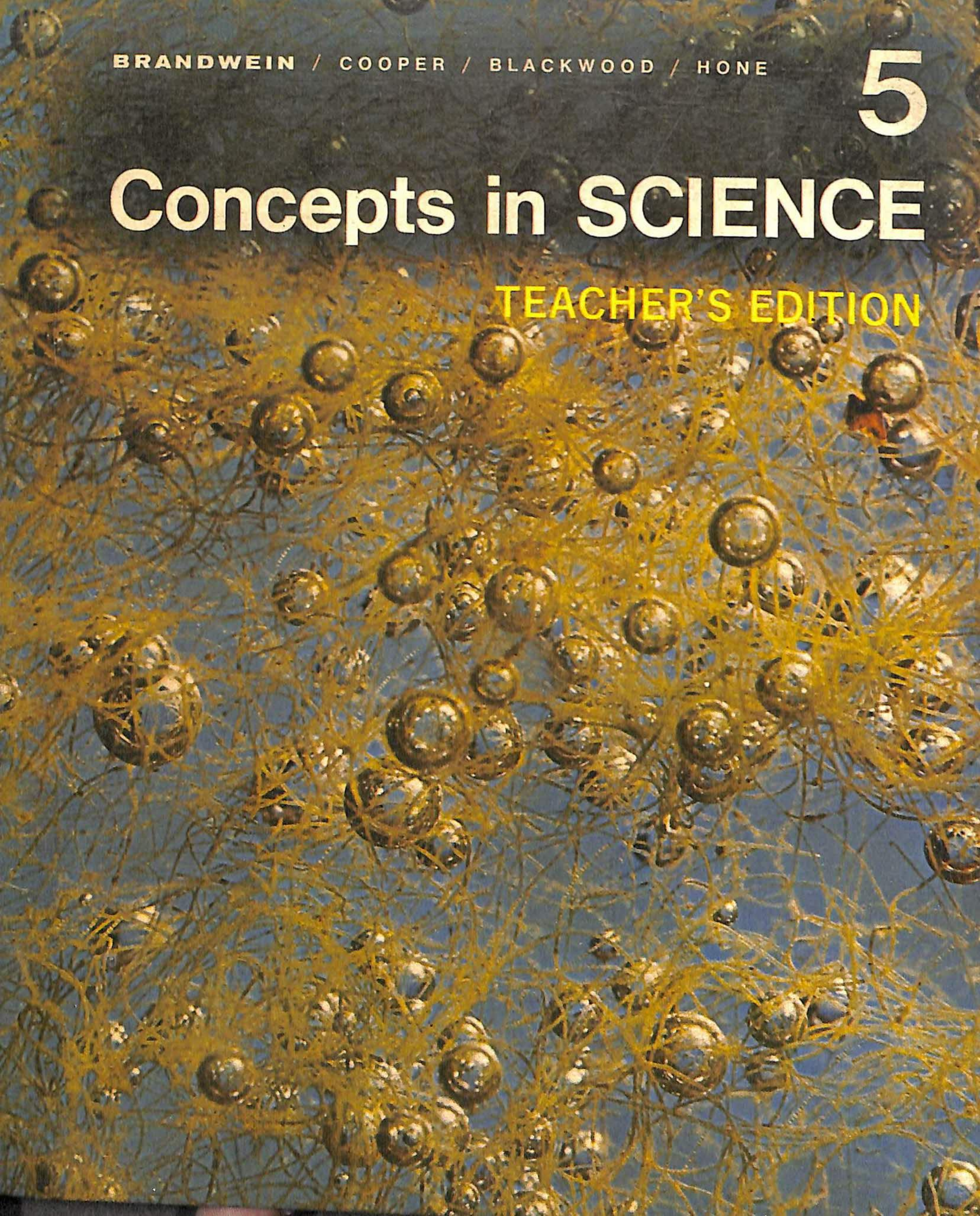

BRANDWEIN / COOPER / BLACKWOOD / HONE

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Concepts in SCIENCE

TEACHER'S EDITION

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Part One: CONCEPTS IN SCIENCE Series

The Teaching of Science

A class of sixth-grade pupils was making a tour of the school grounds with their teacher to note the kinds of machines being used in the construction of an addition to the school. With enthusiasm they commented on the cranes, derricks, and bulldozers that were moving earth and construction materials around. As they stopped near some heavy planks and a pile of building stone, the teacher said, "I can invent a machine with these materials so that the smallest one of you can easily lift two of the heaviest." Some of the pupils grinned with disbelief; others were more vocal. Two or three, proud and impatient with knowledge, offered the solution, "You're going to make a lever." But still there was skepticism. The teacher selected a stone, arranged one of the heavy boards over it, asked two of the larger pupils to stand on the end that was nearest the stone, and then selected one of the more vocal disbelievers to lift the two pupils. Of course, the invention worked. The lever multiplied the force of the smaller pupil, as many machines do.

How do machines work? The pupils returned to the classroom, which was now a laboratory. There, during the course of a number of days, they made models of different kinds of machines, investigated how they multiplied force or changed the direction in which the force was applied or increased speed. They invented variations on machines that would multiply the force of muscles and they combined them. They performed mathematical calculations and arrived at certain relationships. At one point, the teacher connected a coil of wire to a dry cell, inserted an iron spike, and picked up a pile of steel tacks. From there the class proceeded to study how inventive persons who understood concepts of science found ways to substitute other sources of energy for man's muscles. During all these investigations the pupils tested their understanding. They collected and recorded data. They used books to check their observations. They interpreted their data and exchanged views of their interpretations. They were, in short, engaged in the processes o science. They were also engaged, as we shall see, in the process of concept-seeking and concept-forming. And they were also using their minds to invent ways to use concepts in doing the world's work.

Now, none of what was done in this school yard and classroom will seem unusual to the imaginative teacher. What is of consequence to teachers and curriculum makers (and writers) is that such experiences should not become merely isolated parts of teaching science, that indeed, in the teaching of science, there should be a structure that is sound in itself. What the teacher was doing with the lever in the school yard and in the classroom was to use technology (in this instance, a lever and fulcrum) to create a situation through which children discovered concepts of science. We prefer to say that a good teaching program *uncovers* the concepts of science. Piaget's classical statement on this subject amounts, eventually, to this: the teacher creates situations through which children discover structure. By "structure" he meant relationships or likenesses among objects and events. A concept is a grouping of relationships, of likenesses, which explains objects and events in the world about us. Each of us tends to uncover the relationship at some particular time, but of course the relationship had been operating in the world before we came on the scene. A concept is new only to scientists, or to us, or to the children. The teacher's art lies precisely in the creating of situations through which children uncover concepts. This appears to be a plain and clear prescription, but of course there are some extremely complex problems confronting the teacher.

There is, obviously, the weight of the teacher's responsibility in teaching science today. In the second half of the twentieth century, children are born in a science-oriented world, in a culture tha puts an extraordinary premium on scientific though and on scientific production. It is sensible to predict that most jobs in the future, including that of teaching, will call for scientific orientation of one degree or another. Contemporary-minded teachers must teach science because society demands it. Helping children to undertake a progressively more sophisticated intellectual activity is a central function in teaching, and creating productive situations—that is, the learning environment—is the teacher's day-to-day responsibility. It is, in many respects, an awesome one. Which situations—of all the countless ones that might be created—is the teacher to select? How is she to cope with the incredible diversity of scientific information, and indeed, with the diversity of children themselves?

From the time children are born, they watch, smell, feel, and listen: they are sentient to the objects and processes of the world. What they know largely derives from their senses and from their perceptions and from the number and kinds of experiences they have had. They acquire meaning, whether true or false, from many kinds of experience—in the classroom, in backyard play, in the streets, in the kitchen, in solitary reflection. They ask questions and examine things and ask still more questions. Because among individuals sensory perception varies and because human experiences vary in both kind and number, no two children begin school with the same knowledge, or with the same set of experiences. It cannot be presumed, therefore, that within the school framework they will move with equal speed or along precisely similar lines of growth. Some kind of provision has to be made to accommodate children of varying experience and of varying ability, and that provision is not alone concerned with the broader questions of homogeneous grouping in schools or of an ungraded curriculum; it is also concerned with providing a scientifically sound structure of learning and teaching science that enables children to uncover the concepts of science in an orderly (though not overly prescriptive) way and at a pace of their individual competency.

A structure in the teaching of science is needed not only to accommodate the phenomenon of diversity in children but also to manage the diversity of the content of science. Scientific research papers are currently being published at the rate of 67,000 words a minute! That amounts to a body of information that would fill eleven sets of a thirty-volume encyclopedia every twenty-four hours. Quite obviously, unless an attempt is made to evaluate, to select, and to sort new information into some kind of structure for the classroom, teachers will fall further and further behind. There is, moreover, the necessity to recognize that scientific knowledge, while it proceeds from facts, is not in itself the mastery of facts. Facts become meaningful, and the awareness of facts ultimately becomes productive, when they are perceived within the structure of basic concepts. We may modify George Gaylord Simpson's definition of science slightly. *Science is the exploration of the material universe for the purpose of seeking orderly explanations of objects and events, explanations that must be testable.* The products of science—which are its orderly explanations and the technology that results from the particular application of them—are the results of certain processes. The processes comprise, first, the observation and examination of data, including experimentation; second, the formulation of explanations by means of inventing hypotheses and stating theories; and third, the testing of the explanations. But the product of all this, the explanations, leads inevitably to other explorations and still other explanations. There are ends in science, but there is no end to science itself.

In their activity, scientists engage in concept-seeking and in concept-forming, and as a matter of course, in concept-testing. This is clearly a function of scientific inquiry. But what do children do when they are engaged in scientific activity? They explore the material universe (observe a plant grow, observe an object move down an inclined plane, observe a balloon that has been untied shoot through the air) and they seek orderly explanations of the objects and events they observe. They also investigate, and where possible, they might even experiment (although in a school context it is most difficult for students to perform an experiment in the *pure* sense, simply because all the variables are difficult to control). They verify the data obtained from observations and they seek to interpret the data. They seek to predict results on the basis of the knowledge they have gained. They attempt to uncover explanations that reliably relate seemingly disparate or "discrepant" objects and events, and that will make prediction of other events possible. They are engaged in understanding concepts of science and in applying them to the world about them.

Identifying the basic concepts of science is not the discrete task of the teacher. The teacher has the right to expect that she will be given help in identifying concepts and in forming a structure for the teaching of science, and this is a shared responsibility that the *Concepts in Science* authors and publisher, and the scientists and teachers who have advised them, have accepted. They recognize that school is time-binding, that work goes on in a certain time span—grades, terms, years—and that many teachers share in the development of each child. They know that a teacher must have a notion of what school experiences children have had before they come into her ken, as well as what will follow once they leave her. The need for a curriculum in science which gives the teacher scope and flexibility is plain enough; what is sometimes not so plain is the need for a curriculum that has a scientifically sound and pedagogically sound structure. We have attempted to give structure to the teaching of science during the first nine years of schooling by informing the processes of science with an understanding of the concepts. We have, in short, sought to identify and define a structure that is not only verifiable scientifically but also viable (practical, productive) in teaching. The conceptual approach is central, in our view, to both aims, both to sound science and sound teaching.

A Modern Science Curriculum

Early in the twentieth century the school curriculum in the United States tended to be content-centered, or disciplinary. During the twenties and thirties this curricular approach gave way to a so-called child-centered approach; the emphasis was shifted—this is overstated for purposes of simplification—from the subject to the learner. Today, still another shift is occurring as content is being placed in a stronger and more relevant role in the curriculum. More and more the emphasis is placed on the interrelationship, more specifically the interaction, between the discipline and the pupil in the learning act. Again with some oversimplification, the contemporary curriculum can be said to be process-centered. Certainly this is apparent in science teaching, and the advance of this kind of curriculum has been most directly aided by the involvement of scientists in the elementary and secondary schools. They have been enormously helpful in proposing a teaching structure for the early school years of science study.

Within the various disciplines of science—biology, chemistry, physics, geology, etc.—data accumulate and change at a bewildering rate. Change is constant. Yet the concepts of science—which are a patterning of facts and a statement of the relationships between observable events and objects—are relatively stable. In a changing world, concepts offer, for this and other reasons, a reasonable foundation for the building of a science curriculum. They are, in a true sense, guides as well as aids to learning.

All of us have the task of sorting out events that come to our awareness in haphazard sequence. All of us have the task of discovering which of the objects and events we perceive are significant and which are not. To bring order out of our haphazard perceptions, we tend to seek a grouping of likenesses among a number of objects and events perceived; in short, we tend to seek concepts. To form a concept, we assort or group objects and events according to their attributes and properties, and we define categories. An example of what is meant by the "attributes" of an object or event will be useful.

A stone has shape, color, weight, and the like; these are some of the attributes of a stone. A bird also has shape, color, weight. Yet there are other attributes of the stone—for example, immobility and hardness, which we recognize as part and parcel of "stoneness." A bird, on the other hand, has mobility, it has feathers, it has egg-laying propensities, and it has a certain structure (from beak to tail)—these and other attributes we recognize as essential to "birdness." In forming a concept, the brain selects those essential attributes (those which discriminate one object from another) which signal the whole configuration of the object or event. Thus the weight of an object is generally not an essential or discriminatory attribute; an attribute of a weight of one pound might apply to a one-pound chicken or a one-pound stone. But "feather" or "beak" is a signal, or cue, for categorizing or concept-forming. It is a signal of the whole concept of "birdness" and it enables us to fill in certain other essential attributes.

Now in learning, the *act of concept-forming* enables an individual to infer; from a few signals or cues he can infer a significant grouping, or category, of like attributes. These signs or cues can be related to *objects* (stones, birds, simple machines) or to *events*, such as the changing of one form of energy to another (for example, the friction of the hands resulting in heat, or the reproduction of organisms, or the splitting of an atom). A specific example in the teaching of a concept, in developing the ability in children to group the like attributes of an event, can be given here. Suppose we wished to create situations through which children would uncover the events that can be grouped within the concept: *In chemical or physical changes, the total amount of matter remains unchanged.* This is precisely the objective of Unit Two in *Concepts in Science 5*. A series of lessons is organized in a sequence in which situations are created whereby children come to *associate* an entire set of attributes of this concept: *In chemical or physical changes, the total amount of matter remains unchanged.* Even if children were to undertake the performance of only the eight investigations in the unit, they would be engaging in the selection of essential attributes of atoms and molecules. This would enable them, in turn, to predict a chemical change from one signal, say, a precipitate. But the text suggests activity after activity—breaking down a molecule, preparing iron oxide from iron and oxygen, testing for acids and bases with litmus paper, testing for production of carbon dioxide. All these are observed and analyzed. Perhaps you would care to examine Unit Two now for a fuller exposition of the way the text assists the teacher in creating situations through which children engage in concept-seeking and concept-formation. But, of course, the text is only part of a very rich program of science in which process is central (see pages F-16—18).

In brief definition, then, *a concept is a mental construct; it is a grouping of the common elements or attributes shared by certain objects and events.* Once a concept is attained, economy in future learning is also attained. For by engaging in the processes of concept-formation, the learner is active in selecting the essential attributes of the complete event, such as "in chemical and physical changes, the total amount of matter remains unchanged." And the learner is enabled to predict an entire sequence of events, or an entire set of characteristics or properties, from a small number of cues or signs. Thus a precipitate, an oxide, or a change in an indicator, is a cue signalizing an entire event.

Defined in other words, a concept is a network of inferences stemming from observation of objects and events, resulting in the selection of common elements, or like attributes, among the objects and events under observation. Identifying and organizing the common, or like, attributes result in a significant category or grouping. That significant category is a concept. A concept is practical and useful because the perception of a small number of attributes, cues, or signals, brings the whole object or event into satisfying recognition. To repeat, a precipitate brings to mind the objects (the molecules involved) and the event (chemical change).

Because we are teaching children, it is well to *group* experiences in a way which will enable teachers to plan their work sequentially. Hence we have ordered the *concept structure of the curriculum you have in hand.* It provides for small blocks of experiences, dealing with objects and events with similar attributes which young children can handle. We have attempted, moreover, to develop a curricular structure which bears some correspondence to the school year, day, and period. Further, for purposes of readier facility in planning the work of the first six years of elementary school, we have grouped a given series of concepts under a still larger category which we call a *conceptual scheme.*

Conceptual schemes provide, we believe, a framework within which the teacher can provide experiences that will lead students to participate in the processes of science—in observation and in interpretation—and emerge with the products of science, which are testable explanations of the workings of the material world. This seems to be a large order. It is. The authors and publisher have spent eight years in the preparation of the curricular organization and materials in this program. They have tested their performance during hundreds of hours in typical classrooms. It is their belief that the conceptual approach is a feasible one that will produce excellent results. In an ultimate sense, their aim is to help the teacher produce an interaction between discipline and student, between the subject and the learner. For this reason, content is never skimped. For each grade there is a hard core of content or subject matter that exceeds more than even the bright child will be able to encompass in the time he is generally allowed.

What has been done in this program, then, is to lay out a framework of conceptual schemes through the first six years of schooling. The framework is capacious. It does not fix the teacher or the student into an inflexible curriculum. On the contrary, it gives the teacher freedom to plan a variety of experiences and it gives the student freedom to plot his own experiences. In both instances, however, the experiences will be ones which are relevant to a search for meaning rather than for the random acquisition of facts. In a real sense, understanding is made simpler for children when they are able to conceptualize—to see patterns in their environment, to group objects and events on the basis of their common elements. A program that accomplishes this is essentially an economical one, economical in the time that is spent in learning. Because, as has been said earlier, concepts remain relatively stable, concepts provide an organization of information that is relatively stable. New observations, new data, variant experiences can all be fitted into the conceptual framework.°

Teachers in St. Mary's County, Maryland, have been experimenting successfully with an elementary science curriculum based on conceptual schemes. Their course of study, initially developed by a curriculum committee, is now in its sixth year of development. Similar courses of study have been developed by other schools and school systems, particularly the Nova School, Fort Lauderdale, Florida.

If we interpret the psychology of learning (so far as it has advanced, which admittedly is not far enough!) with any degree of acuity, then we assume that it is important for children to learn in "wholes." In this sense, concepts are "wholes." Moreover, if we accept the definition that education should result in a change of behavior in the student, then an understanding of concepts will provide a person with intelligent means of deciding among alternatives. The conservation of natural resources; the support of public health programs; the questions of population growth; the fallacies in ethnic discrimination—all these are civic and social matters that confront a contemporary person. He is better able to judge what he perceives, and better able to support what he believes, when he understands the basic scientific concepts. The teaching of science ought to do more than dispel ignorance and superstition; it ought to help provide means by which a human being can comprehend what is today known but still unseen or still not widely operative. Exploration of the moon is a certainty, even though it has not yet happened.

The *Concepts in Science* series is an elementary science curriculum which attempts to reflect commonly accepted and basic ideas of contemporary scientists, cognitive psychologists, and teachers. It is a systematic organization of instructional materials. It is also a laboratory-centered program. The framework of six conceptual schemes provides a learning sequence that is shown, in broad outline, on the chart on pages F–14 and F–15. The sequential development is represented on the chart as horizontal threads called *concept levels*, which increase in complexity as one advances from one level to the next.

The National Science Teachers Association Committee on curriculum development, in "Theory in Action,"° suggests seven conceptual schemes. The Committee agrees upon twelve statements. Seven of these statements discuss conceptual schemes, and five of them describe the process of science as the base for science curriculum planning. In the *Concepts in Science* series, the concepts have been grouped under six conceptual schemes, but the differences between this organization and that of "Theory in Action" is not substantial or finally consequential. The authors suggest that the content of the science curriculum could be arranged in an orderly structure under six conceptual schemes in a way that effects economy in organization, time, and effort.

° See *A Study of Thinking* by Jerome S. Bruner, Jacqueline J. Goodnow, George A. Austin, John Wiley & Sons, Inc., New York, 1956.

° Published by the National Science Teachers Association, 1964.

A Comprehensive Program

The major conceptual schemes can be stated in somewhat arbitrary terms; no doubt, different teachers will state them differently. Certainly they would be stated differently for the scientist-specialist than for the elementary-school teacher, who of necessity teaches not only science but English and social studies. Certainly the statements may be modified and restated under different conditions, with different pupils and in different schools. Yet the authors have chosen to state the conceptual schemes in terms that can be used throughout the particular content and activities in the *Concepts in Science* series.

A Framework of Conceptual Schemes

The conceptual schemes and the general areas they subtend are:

1. When energy changes from one form to another, the total amount of energy remains unchanged.

Energy transformation is a common phenomenon. If you rub your hands, mechanical energy is converted to heat energy. If you burn a candle, chemical energy is converted to heat and light; and in a dry cell, chemical energy can be converted to electric energy. But whether one is concerned with burning oil in the home, gasoline in the automobile, glucose in the body, or whether one is concerned with the transfer of the energy of moving water into a flow of electrons in a conductor, the total amount of energy in any given system remains unchanged. This conceptual scheme is a primary concern in the discipline of physics.

2. When matter changes from one form to another, the total amount of matter remains unchanged.

The world of matter consists of a world of things, from the very large bodies—stars, planets, moons, and other celestial bodies—to the very small particles—atoms, molecules, and subatomic particles. As the matter in the universe undergoes physical change, a change of state, and chemical change, a change in form, the total amount of matter undergoing chemical or physical change in any given system remains unchanged. This conceptual scheme lies within the discipline of chemistry.

3. Living things are interdependent with one another and with their environment.

Around living things everywhere, there exists an environment of matter and energy; indeed, living things cannot be considered apart from their environment. Plants depend upon their environment for their growth and development. Green plants capture energy from the Sun in the photosynthetic process; animals, in turn, transform the chemical energy of plants. And finally, all plants and animals yield their matter and energy as they die and decay. In addition, the demands of living in a given environment result in a relationship between plants and animals in communities that display definite characteristics—deserts, forests, seas, ponds, etc. For example, the sea is an environment in which ninety percent of the world's photosynthesis takes place, where complex food niches are developed, and intricate reproductive cycles operate. Understanding these interrelationships results in our ability to predict, within limits, the behavior and development of plants and animals. The conceptual scheme that describes them is a part of the study of biology.

4. A living thing is the product of its heredity and environment.

Within this conceptual scheme, one can develop the concept of an organism that lives in a kind of dynamic equilibrium. The organism is never the result purely of its heredity but of the environment interacting with hereditary factors. This is true of any specific trait. This is also important to comprehend in a human being's realization of full physical development and vigorous health. Other examples:

A red barberry is greenish unless exposed to strong sunlight.
An intelligent child needs an education.
Beets in acid soil are stunted.
A child lacking vitamin B may develop beriberi.
A potato seedling in the dark is attenuated.
A child poorly fed and poorly housed does not resist tuberculosis as well as one who lives in a more salutary environment.

The full range of the development of organisms—including the study of reproduction, genetics, growth, nutrition, behavior, and adaptation to the environment—is involved in this conceptual scheme, which is the concern of several sciences: genetics, physiology, and biochemistry.

5. Living things are in constant change.

The universe changes; the Earth changes; the single organism and the species change over the ages. The concepts of adaptation over the ages, divergence in form, convergence in geographical isolation, and evolution are within the purview of this conceptual scheme, which involves genetics and ecology.

6. The universe is in constant change.

Every child today seems to know that the solar system is changing. Certainly the earth's atmosphere is constantly shifting. The Earth is in constant motion; the Sun is in constant eruption. We note the appearance of novas and supernovas. We observe and gain evidence from Cepheid variables. We interpret the red shift in starlight to indicate an expanding universe in constant change. The change in the universe comprises a conceptual scheme that is the primary concern of geology, astronomy, and meteorology.

A Developmental Structure of Concepts. Expectedly, as the concepts in science are selected to fit the purposes of instruction in the elementary school, they seem to group themselves easily. The rationale is this: first, concepts should fall easily into a particular conceptual scheme; second, they should be ordered from the simple to the complex. "Simple" is used here in the sense that the experiences provided should be simple. Young children do not deal with a complexity of cause and effect, that is, with *multiple variables*. For example, it is fairly easy in the second grade or level to deal with the concept *related living things reproduce in similar ways*. On the other hand, the concept *the characteristics of a living thing are laid down in a genetic code* requires that we make available more complex experiences which are appropriate at higher levels. All this is not to imply that some children cannot deal with more complex structures even while the norm for a class is said to be a concept development at a lower level. A particular advantage of a conceptual structure in the curriculum is the provision for extended or accelerated growth in individual children. For instance, if a child seems to understand a concept at a higher level of complexity than his classmates, the teacher can determine the level of understanding by asking appropriate questions at a lower concept level (pages F–14—15). If a sufficient number of children are able to deal with a higher concept level, procedures may then be modified.

The organization of a curriculum in terms of concept levels accommodates its own "multiple tracking." As a result, it is possible to have groups, or even individuals within the same class, proceed at different rates up the concept "rungs" of the conceptual "ladder." They can engage in experiences which are appropriate to their level of understanding, and at the same time communicate with groups at other concept levels. In other words, they are all on the same ladder, if on different rungs. In any event, a teacher will certainly wish to know the entire conceptual structure. The structure for *Concepts in Science 1–6* is charted on pages F–14—15.

The concepts which form the rungs of the conceptual ladder can be stated in various ways, but the central purpose is to organize them in graduated order so that understanding of one (in a lower level) precedes the next for purposes of greater comprehension and utilization. There is some danger, we believe, in stating a conceptual scheme (or even a concept) by a single term (for example, *energy, matter, life*). However convenient this may seem, such easy rubrics may have the effect of limiting the implications of this approach to science study.

Now, the structure for science in the first six grades of the elementary school, here given as six conceptual schemes, with the concepts given at six levels (not necessarily grades), is purely for convenience and custom. The levels, until research proves this unwise, are in a rough order of precedence. Naturally, each concept has a number of subconcepts; the development of subconcepts depends on the judgment of the teacher.

The essence of science is *investigation of the material universe*. Its goals consist of a search for meaning; indeed Albert Einstein once defined it as experience in search of meaning; it *seeks orderly explanations (conceptualizations) of phenomena, the objects and events about us*. Nevertheless, there is stubborn insistence by scientists that an orderly explanation *be testable*. If a concept is not testable, it is usually not acceptable. Science is, in

A STRUCTURE FOR

	CONCEPTUAL SCHEME A **When energy changes from one form to another, the total amount of energy remains unchanged.**	**CONCEPTUAL SCHEME B** **When matter changes from one form to another, the total amount of matter remains unchanged.**	**CONCEPTUAL SCHEME C** **Living things are interdependent with one another and with their environment.**
CONCEPT LEVEL VI	The amount of energy gotten out of a machine does not exceed the energy put into it.	In nuclear reactions, a loss of matter is a gain in energy; the sum of the matter and energy remains constant.	Living things are adapted by structure and function to their environment.
CONCEPT LEVEL V	Energy must be applied to produce an unbalanced force, resulting in motion or change of motion.	In chemical or physical changes, the total amount of matter remains unchanged.	The capture of radiant energy by green plants is basic to the growth and maintenance of all living things.
CONCEPT LEVEL IV	A loss or gain of energy affects molecular motion.	In chemical change, atoms react to produce change in the molecules.	Living things capture matter from the environment and return it to the environment.
CONCEPT LEVEL III	The Sun is the Earth's chief source of radiant energy.	Matter consists of atoms and molecules.	There are characteristic environments, each with their characteristic life.
CONCEPT LEVEL II	Energy can change from one form to another.	A change in the state of matter is determined by molecular motion.	Living things depend on their environment for the conditions of life.
CONCEPT LEVEL I	Energy must be used to set an object in motion. There are many forms of energy.	Matter commonly exists as solids, liquids, and gases.	Living things are affected by their environment.
	CONCEPTUAL SCHEME A **When energy changes from one form to another, the total amount of energy remains unchanged.**	**CONCEPTUAL SCHEME B** **When matter changes from one form to another, the total amount of matter remains unchanged.**	**CONCEPTUAL SCHEME C** **Living things are interdependent with one another and with their environment.**

CONCEPTUAL SCHEME D **A living thing is the product of its heredity and environment.**	**CONCEPTUAL SCHEME E** **Living things are in constant change.**	**CONCEPTUAL SCHEME F** **The universe is in constant change.**	
The characteristics of a living thing are laid down in a genetic code.	Changes in the genetic code produce changes in living things.	Nuclear reactions produce the radiant energy of stars, and consequent change.	**CONCEPT LEVEL VI**
The cell is the unit of structure and function; a living thing develops from a single cell.	Living things have changed over the ages.	Bodies in space (as well as their matter and energy) are in constant change.	**CONCEPT LEVEL V**
A living thing reproduces itself and develops in a given environment.	The environment is in constant change.	The motion and path of celestial bodies are predictable.	**CONCEPT LEVEL IV**
Living things are related through possession of common structure.	Living things grow and develop in different environments.	There are seasonal and annual changes within the solar system.	**CONCEPT LEVEL III**
Related living things reproduce in similar ways.	Forms of living things have become extinct.	There are regular movements of the Earth and Moon.	**CONCEPT LEVEL II**
Living things reproduce.	There are different forms of living things.	There are daily changes on Earth.	**CONCEPT LEVEL I**
CONCEPTUAL SCHEME D **A living thing is the product of its heredity and environment.**	**CONCEPTUAL SCHEME E** **Living things are in constant change.**	**CONCEPTUAL SCHEME F** **The universe is in constant change.**	

short, the "art of investigation" (Beveridge's term). But one cannot investigate an object or event if the object or event is not first perceived.

This book is literally a sourcebook of situations in which children participate and perceive objects and events. In creating a learning situation, children are given opportunity to seek the attributes of objects and events and to seek hidden likenesses. In the situation described on page F–7, the sixth-grade children engaged in these processes: they *observed* the working of a lever; they *investigated* the relationship between machines and forces; they *collected* relevant data; they *described* the operation of the lever and other simple machines; they *discussed* their results; they *confirmed* one another's results (through collaborating in an investigation); they *read* the work of scientists; they *invented* and then *reported* their results in a kind of colloquium. Note the processes: observation, investigation, collection of relevant data, description of results, discussion of findings, confirmation of findings, reading the work of scientists, exercising inventiveness, reporting of work, and within limits, experimentation, among other processes.

RESOURCES FOR A COMPREHENSIVE PROGRAM

The structure of science and the processes of science yield knowledge and they yield understanding but at no time could they exist without the materials of science—materials which provide the media for investigation, whether the investigation involves reading a textbook or carrying out a sophisticated experiment in the laboratory. The materials for *Concepts in Science* include the facts of science as well as the tools of science. These materials come in the form of reading matter, illustrations, manipulative objects, laboratory guides, testing instruments, and other aids to teaching.

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TEXTBOOKS

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While the full-color photographs and drawings enhance the visual quality of the textbooks, they serve the important function throughout the program of training children to observe with discrimination the pictorial representations of their physical environment. Many of the photographs are of actual performances by pupils and experienced teachers in the classroom.

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The reading vocabulary has been carefully controlled for the grade level throughout the program, with due attention to the adequate presentation of technical vocabulary necessary to understanding concepts in science. In *Concepts in Science 3* and *4*, a pronunciation-at-sight system is used; and in *Concepts in Science 5* and *6*, a standard system of diacritical marking is used.

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While the contents of the individual laboratories differ, depending on grade level, each one contains a tray of commonly-used apparatus: beakers, test tubes, tripods, plastic tumblers, plastic dishes, and other basic materials which can be reused whenever needed. With normal use, some depletion of parts will occur each year and a small portion of the items are consumable. Replacements are available from the publisher.

WORKBOOKS

Concepts in Science Workbooks, available for Grades 4 through 6, give pupils additional opportunity to reinforce and extend their understanding of the concepts developed in the *Concepts in Science* textbooks. Through the experiences that are provided in these workbooks, pupils review concepts and apply them in new context. New problems are introduced which are related to problems they have already studied, but which differ in some significant way from those in the textbooks. Moreover, the workbooks give additional practice in utilizing basic laboratory skills—recording observations, tabulating data, interpreting data, and drawing conclusions—as well as practice in using scientific apparatus. The activities in the workbooks have been selected to provide experiences in various situations—at home, in the classroom, on a field trip, in the library, or in the laboratory; and from these experiences, pupils are called upon to organize and apply the concepts and skills initiated and developed in their textbooks. Self-testing reviews are included for additional pupil evaluation and a Teacher's Correction Key, separately available, provides suggested answers.

TESTS

Teaching Tests, prepared and screened by the Harcourt, Brace & World Science Testing Board, are available separately for *Concepts in Science 3* through 6. The answer keys are found in the Teacher's Editions of the textbooks.

These tests, to be used after each unit in the pupil's books, go beyond the testing of facts. Like other elements in the *Concepts in Science* program, they help teachers evaluate the pupil's understanding of concepts. The questions for each test are designed to evaluate comprehension as well as retention of information. They are divided into several parts; the parts are designed to test the child's ability to read for comprehension and interpretation, the ability to recall factual information, the ability to evaluate and apply concepts in new situations. They may also determine how well the pupils perceive relationships among the concepts developed.

LABORATORY CARDS

100 Invitations to Investigate, a set of 100 ungraded laboratory cards, provide the background information, illustrations, and clues to procedure for pupils' independent investigations. The investigations are a random assortment in the biological, physical, and chemical sciences; they progress in difficulty—the higher numbered investigations being more sophisticated. The cards, which are packaged in a sturdy case, are designed for those pupils who wish to pursue, beyond what is covered in the textbook, their own interest in some particular area of science, independent of their regular classroom work. Each child is encouraged to select the investigation in which he is interested, to investigate with enthusiasm and imagination, to seek answers to problems for which his textbook offers no solution. While designed for enrichment, the laboratory cards also lend themselves to science study by specially interested students and for science in ungraded programs.

SOURCEBOOKS FOR THE TEACHER

Harcourt, Brace & World publishes a number of professional books which provide supplementary information for teachers on how to plan, prepare for, and carry out a science program in the elementary school. Written by specialists in the field of science education, these books provide the "tactics and strategy" as well as the techniques for teaching elementary and high school science. They also employ the scientific and educational psychology involved in the teaching of science. You will find a list of these publications on the first page.

Part Two: CONCEPTS IN SCIENCE 5

Structure and Content

Concepts in Science 5 is more than a series of related sections in eight units. It is more than the sum of its separate parts. It is the fifth in a series of six books of an elementary science curriculum. It is a part of a sequential and fully articulated program in which each unit has dependence upon the content of units previously studied. Each section in the textbook is part of the larger pattern of the unit. The unit, in turn, is part of a still larger pattern, the year's work in science, which encompasses the six conceptual schemes at the concept level indicated on pages F-14—15.

Science concepts are interrelated. Change, for instance, is introduced in Unit One in relation to the study of the Earth and its structure. In later units, change is reintroduced and reused in relation to physical and chemical change, matter and energy, growth of plants, the development of the human body, the development of living things over the ages, and in a study of other bodies in the solar system. The concepts of matter, energy, interdependence, etc., are similarly introduced, reintroduced, and reused in more than a single unit.

The conceptual schemes that are set forth in this Teacher's Edition, and the subconcepts which serve them, lend themselves to providing basic experiences for children as they study the objects and events in the world around them. A concept learned in one unit is recalled and reapplied in new context in later units.

In *Concepts in Science* 5, the eight units develop the fifth concept level of the six major conceptual schemes. Each unit is primarily concerned with one conceptual scheme, but some schemes appear in more than one unit. The eight units deal with a variety of subjects: erosion and mountain building, atoms and molecules, elements and compounds, inertia and motion, gravitation, cells and organ systems, photosynthesis and interdependence, light and the stars, fossils and changing environments—to give but a partial list. Yet, to the scientist, these units are concerned with only three larger categories: energy, matter, and life. These three categories have been studied in earlier textbooks in the series and will be studied again, on succeeding levels of increasing sophistication in relation to what the authors have chosen to call the six major conceptual schemes—schemes that are basic to the child's understanding of the material universe.

Earlier concept levels for each conceptual scheme are basic to understanding the scheme as it is developed on this and succeeding concept levels. *Concepts in Science* 5 builds upon earlier levels. The conceptual schemes are not *taught* to the children; rather, they are the eventual goals the children, as learners, reach through experiences selected to provide a maximum of individual involvement in the learning process. Concept formation proceeds step-by-step through all the grades.

The exploration of the environment, certainly a major aim of science, does not begin in the first grade, nor end in the fifth. Most young children enter school with a fund of science information (and misinformation) and a fairly well-developed pattern of behavior that has served their need to satisfy their natural curiosity. By the fifth grade they have had new experiences, many that have been planned in search of meaning. In school, their experiences have been selected and organized for conceptual understanding, a necessity if the search is to be successful.

In each grade, teachers help children to organize and evaluate their information, and to use and improve their habits and skills of investigating. Their investigating, however, proceeds no longer in the random fashion of early childhood; rather, it proceeds through thoughtful selection of the processes of scientific investigation in a sequential, developmental pattern of experiences systematically organized as a science curriculum. Let us examine the pattern in *Concepts in Science* 5, as it is developed in the textbook and Teacher's Edition.

THE STRUCTURE OF A UNIT

All the units in the child's textbook have the same structure and the same component parts. All the units in this Teacher's Edition exactly parallel the structure of the child's textbook, except, of course, that the statements of the conceptual goals of the teaching and learning processes are not included in the child's textbook. All the teaching suggestions for each unit directly precede the reproduced pages of the child's textbook and are readily identifiable by the color bands on the outside margin.

Since you will be starting with Unit One, "The Earth—Inside and Out," a brief analysis of the teaching suggestions on pages T–1—22 will serve to explain the main headings and help in developing an approach to teaching the sections in this and subsequent units.

Across the top of page T–1 is a statement of the **Conceptual Scheme** followed by the **title of the unit** and a notation of the pages of the child's textbook to which the teaching suggestions refer. In the margin appears a statement of the **Unit Concept.** Reference to the chart on pages F–14—15 shows that this Unit Concept for Unit One thus deals with Concept Level V of Conceptual Scheme F. Similarly, other units are seen directly to fit the same concept level of one or another of the six conceptual schemes.

Next to the Unit Concept statement is an interpretation for the teacher that is related to questions children are likely to ask, observations they may make, or procedures they will use in working toward the goal of concept formation and conceptual understanding.

In "A View of the Unit," which immediately follows the title of the unit, it is recognized that teachers have many claims upon their time and energies. This preview of the concepts not only summarizes the subconcepts that supply the evidential base for the unit concept, but also provides background information that often goes considerably beyond the fifth-grade level. It is hoped that this introduction will render it unnecessary that a teacher do further research before beginning to teach the unit with confidence and enthusiasm.

Under "Supplementary Aids" (see pages T–2—5), there is a graded listing of films and filmstrips for classroom showing, as well as books for the science reading table. The films and filmstrips have been previewed, selected, and rated by Bess S. King, formerly supervisor of Santa Monica Public Schools, Santa Monica, California. A "primary" rating indicates that the concepts are relatively easy to comprehend, while a "junior high school" rating indicates they are relatively advanced for fifth grade, but useful if their presentation is carefully guided. The books suggested for the science reading table were reviewed, selected, and graded for reading level and conceptual content by Ester K. Nelson, Consultant in Elementary Education, Bureau of Elementary Education, California State Department of Education, Sacramento, California. The authors of *Concepts in Science* unhesitatingly concur with the choices. The *Classroom Laboratory* and other items for a comprehensive program are described on pages F–17—18.

Suggestions for **Introducing the Unit** (see page T–5), together with the opening two pages of the unit in the child's textbook, serve to stimulate curiosity and link thought to action. They lead directly into the teaching suggestions for Section 1 of the unit.

The Pattern of a Section. Examination of the opening lines of a section (see Section 1, page T–6) reveals a pattern identical to that of the opening of the unit: the *title of the section*, the *pages of the child's textbook*, a *statement of the subconcept*, and an *interpretation for the teacher* that is related to the manner in which children will work toward understanding of the subconcept. Note that each subconcept is related to, and fills in, some aspect of the unit concept. Section subconcepts might well be considered as supporting concepts to the larger and more inclusive Unit Concept.

In the margin below the subconcept generally appears a listing of the **Processes emphasized** for the entire section. Not all processes will be used in every activity, nor will these necessarily be the only processes children will use. The teacher immediately sees, for example, that in Section 1 children may be encouraged to observe, take a field trip, investigate, hypothesize, consult with others, report their findings, and invent models. By these processes, and others in different sections, children approach conceptual understanding.

In each section, the child has experiences that enable him to take a specific step toward understanding some important concept. A section may be completed in one day in some instances; in others, several days will be needed. A lesson in this textbook does not imply completion of so many minutes of a classroom assignment, but gaining of an understanding of a concept, even though the child has never seen or heard the concept stated in specific terms.

Like good lessons in subjects other than science, the section has three main divisions:

the introduction—in which a problem is raised and curiosity stimulated; that is, thought is linked to action;
the main body of the lesson—in which the content is organized for concept development and then summarized;
the reinforcement or extension of the lesson—in which a variety of activities is introduced for enrichment.

In the sections, or lessons, the children become aware of new relationships as they discover similarities among objects and events that previously may not have appeared to them to be related. Gradually, as they recognize and understand more clearly some of the more complicated patterns of relationships in the universe, for which they are ready on the fifth-grade level, the children build in depth their concepts in science. These concepts evolve in the child's mind as he takes each experience as a specific step toward understanding of increasingly mature concepts.

Introducing the Concept, the first part of each section, suggests an activity that raises questions or poses a problem. The activity may be a demonstration by the teacher, the making of a model, a class discussion, or a simple investigation. Occasionally some object or objects are desirable for examination. In Section 1 of Unit One (page T–6), this procedure is suggested, and the objects are listed as **Equipment and Materials** in the margin so that the teacher may see at a glance what may be useful to obtain for the opening of the lesson. In fact, wherever any activities are suggested that call for materials, the teacher will find a listing in the margin with a space in which to check their availability.

Once the section has been introduced, the teacher may further stimulate and guide the children's attention and curiosity by asking the pertinent question in bold-face type. To work toward uncovering the answers, the children turn naturally to their science textbooks and continue with the main part of the lesson.

Developing the Concept consists of several activities, usually from three to five, indicated by italic headings. These activities help the child to uncover evidence, see relationships, draw inferences, and in other ways move further toward understanding of the concept. The kind of evidence the children should discover is stated in the margin opposite the italic title. Equipment and materials are listed if necessary, except for the investigations in the child's textbook where the materials are listed in the investigation.

The heart of many of the lessons, or sections, is the *investigation*, always indicated in the child's textbook by the blue-tinted pages. If pitfalls in the investigation can be anticipated, or other learnings or questions may evolve from it, the teacher is alerted in the teaching suggestions. Otherwise, teachers follow the child's textbook and encourage design of the investigation and performance of it at the point indicated. If special equipment or alternate equipment for the investigation is supplied in the *Classroom Laboratory*, the availability of this equipment is indicated in the margin (see pages T–7 and T–9).

It is useful at this point to call attention to the illustrations, both in the text and in the investigation pages. The concepts of science rest upon observed evidence; that is, evidence observed and verified by someone. Unfortunately none of us can observe everything at first hand; in fact, we must rely upon indirect evidence for much that we learn. The evidence of pictures is perhaps the hardest to read. We tend to look at a picture before we know what it is that the picture can tell us—and then we don't come back to it. Or we read all about an object or event before we look at the illustration and often overlook something important that would help fix our understanding. To insure that the picture is "read" at the appropriate time, the picture is cued within the text by a symbol (square, circle, triangle, etc.) in color. Each cue means simply, "Now look at the picture—the one marked with a square." This is the right moment for inspection. There is no difficulty returning to the right point in the text, because the cue is there, clearly visible. Figure numbers and captions, used at higher levels of instruction, would tend, with younger children, to interrupt the reading or set the illustration apart from the context. This cuing of visualizations of evidence gives an improved degree of control over the learning situation.

S.C.E.R.T., West Bengal
Date..........................
Acc. No..........................

In the child's text, the outcome of an investigation can be seen in the photographs illustrating it, as a rule. The text of the investigation does not tell what the outcome will be; the picture must be inspected to see what happened. Thus, the importance of seeing, or observing, is stressed, even if, for some good reason, the investigation is not actually performed. When it is performed, the child has a guide by which to test his own results. However, we must also stress that the photographs show only how *one* trial came out. Scientists seldom accept the evidence of one trial. Variations in the children's results are to be expected. There may be good reasons for the variations, or perhaps the technique may be faulty. Children, then, should be cautioned not to accept one result and encouraged to make several trials to discover reasons for any discrepancies between their results and those pictured.

Extending the Concept, part of the main body of the lesson, but not a requirement of it, provides additional activities in which children may seek out further information in an area that interests them or apply a developed understanding in a new context. Some of these activities are suitable for slower-moving children who need reinforcement on a lower level; others offer a challenge to the more able.

Each section in the child's text closes with several types of activities, ranging from simple self-tests to investigations children may do on their own. Since teachers are busy persons, the answers to factual questions are given under **Reviewing the Concept** (see page T–8). The results of a pupil-planned activity are not indicated. He may achieve a different answer that satisfies the conditions of his activity, or a more extended answer than might be given here. What the child uncovers and can defend on the basis of his own efforts is far more important than his arrival at an expected answer.

A good science lesson rarely ends at the close of a science period. One of the criteria used by teachers in evaluating the effectiveness of their teaching is the enthusiasm with which children continue to observe and investigate on their own. The lesson (section) then serves to point the way and to give meaning to children's continuing observations and investigations in their daily lives.

Closing the Unit. The last section of each unit (see page T–21), titled "The Main Concept," brings the central ideas of the subconcepts together in a summary that relates them to the Unit Concept and to the Conceptual Scheme. It is at this time that children should be encouraged to formulate their own statement of the Unit Concept. The exact words, as printed in the margin, are not important. Each child has his own understanding; any reasonable approximation of a statement of concept relationships should be accepted.

A New View. A comparison of the six conceptual schemes of *Concepts in Science* (pages F–14—15) shows that all these schemes are interrelated. In the fifth grade, children can begin to see these concept relationships and get a glimpse of the unity of the world in which they live. Hence, at three stages during the year's course, children take stock of conceptual relationships in sections titled "A New View." The first of these is "A New View of Matter and Energy," the second "A New View of Living Things," and the third "A New View of Change." In each of the special sections, two conceptual schemes are examined together, as will be evident from a reference to pages T–68 and T–69 at the close of the teaching suggestions for Unit Three. The remaining two "New View" sections are at the close of Unit Six and Unit Eight.

These "New View" sections encourage children to note and appreciate their growth in science. This growth is, of course, individual. But all the children come to some understanding of relationships between concepts. They can and do share an understanding of the world they have explored, each to his own capacity.

At the End of the Year's Work. Following the eight units and the final "New View" section is an end-of-book section titled "On Your Own: Probing the Earth's Crust" (see textbook page 346). Many children enjoy an extended activity; many are inveterate collectors; and still others are attracted by the opportunity to make discoveries on their own, quite independently of classroom experiences. The activities suggested in this section may be started with any child, with any group of children, or used to supplement the work of the text at any time. However this section may be used, it was prepared with the capacities of children to explore, collect, and classify clearly in mind.

For all the children, the text, carefully ordered in concepts, growing in complexity as each child grows in maturity, provides a series of firm foundation stones on which all may be guided to a firmer understanding of the higher ordering of concepts in *Concepts in Science 6*.

The ultimate goal. Each science lesson is designed to permit the child

1. To explore the material universe (through a "mix" of activity);
2. to seek orderly explanations of the objects and events explored (the explanation is an assertion we have called a *concept*);
3. to test his explanations (through a variety of activities).

The teacher's art is an individual one; the child's learning activity is an individual one. Nevertheless, the teacher's art is congruent to the scientist's when the child—in the teacher's hands—explores his world and, because of the teacher's great skill and understanding, is not crushed by the immensity of it.

Each lesson, in short, becomes an experience in search of meaning. A new concept of the way the world works becomes part of the child's equipment; it becomes part of his posture toward the world he lives in. He grows.

Useful Teacher References

Many books in science and science education offer splendid opportunities for additional study and investigations by pupils or for enrichment of teaching background. Harcourt, Brace & World publishes a number of textbooks for higher levels as well as several sourcebooks. Since they are referred to in this Teacher's Edition from time to time, the titles are cited below. In addition, a few other sourcebooks useful for reference and also cited in this Teacher's Edition are listed. Any of these is sufficient in conceptual depth and in richness of content to provide broad avenues of exploration for the most exacting teacher or the most inquisitive, imaginative, or creative child. The names and addresses of all the publishers whose titles are suggested here and in suggestions for individual units are on pages F-24—25.

The World of Living Things by Paul F. Brandwein et al., Harcourt, Brace & World, 1964. A general science textbook for junior high school, stressing biological science at an elementary level.

The World of Matter-Energy by Paul F. Brandwein et al., Harcourt, Brace & World, 1964. A general science textbook for junior high school, stressing earth and physical sciences at an elementary level.

Exploring the Sciences by Paul F. Brandwein et al., Harcourt, Brace & World, 1964. A complete, general science textbook for junior high school.

The Physical World, Second Edition, by Richard Brinckerhoff et al., Harcourt, Brace & World, 1963. A textbook in the physical sciences for ninth-grade pupils. Contains a special section of investigational activities for the more inquisitive and thoughtful pupil.

Teaching Elementary Science: A Sourcebook for Elementary Science by Elizabeth B. Hone et al., Harcourt, Brace & World, 1962. Descriptions of projects and experiments for pupils; techniques, field trips, demonstrations, and suggestions for planning instruction in biological and physical science are presented.

Teaching High School Science: A Sourcebook for the Biological Sciences by Evelyn Morholt et al., Harcourt, Brace & World, 1958. Similar in organization and planning to the elementary sourcebook cited above. Although designed for high school, it contains much useful material for the teacher and for pupils with special interests.

Teaching High School Science: A Sourcebook for the Physical Sciences by Alexander Joseph et al., Harcourt, Brace & World, 1961. Similar to the biological sciences sourcebook cited above, but for the physical science field.

The Body by Alan E. Nourse and the Editors of *Life*, Time, Inc., 1964. The basic approach of structure and function is used to describe the human body. The major organ systems of the body are explained in the light of the most recent discoveries of medical research. Many of the marvelous pictures and diagrams are excellent for pupil study.

The Cell by John Pfeiffer and the Editors of *Life*, Time, Inc., 1964. Recent discoveries about the cell are described in layman's language. Much information and many of the pictures and diagrams will be enthusiastically shared with pupils.

Foundations of Modern Biology Series, Prentice-Hall, 1961. A series of short, illustrated books on modern biology. Hard-to-locate descriptions of recent research and discoveries may be found in these books. The titles and authors are: *Man in Nature* by Marston Bates; *The Plant Kingdom* by Harold C. Bold; *Heredity* by David Bonner; *Animal Behavior* by Vincent Dethier and Eliot Stellar; *The Life of the Green Plant by* Arthur W. Galston; *Animal Diversity* by Earl D. Hanson; *Cellular Physiology and Biochemistry* by William D. McElroy; *Animal Physiology* by Knut Schmidt-Nielsen; *Animal Growth and Development* by Maurice Sussman; *The Cell* by Carl P. Swanson; and *Adaptation* by Bruce Wallace and A. M. Srb.

Geology and Earth Sciences Sourcebook for Elementary and Secondary Schools by Robert Heller, Editor; prepared under the guidance of the American Geological Institute, National Academy of Sciences—National Research Council; Holt, 1962. An encyclopedic reference of unusual readability. Includes sections on minerals, rocks, volcanoes, metamorphism, earthquakes, and the Earth's interior, mountain building, weathering, water, glaciers, mineral resources, astronomy, origin of the Earth, and paleontology.

Science Education for Elementary School Teachers by Harold E. Tannenbaum and Nathan Stillman, Allyn & Bacon, 1960. Chapter 6 of this book is excellent for its suggestions on the use of reference materials.

Teaching Science Through Discovery by Arthur Carin and Robert B. Sund, Merrill, 1964. An intensely practical volume that can help teachers understand and practice a science program for the elementary school in accord with the revolutionary nature of science education. The four section titles, "Shaping Science Education in the Elementary School," "Organizing and Planning for Teaching Science," "Enrichment Activities for Science Teaching-Learning," and "Discovery Lesson Plans and Other Activities for Teaching Science," barely suggest the rationale and framework for science teaching and learning which permeate all sections. Emphasis is on problem solving and the "discovery approach," but specific, detailed, step-by-step activities for organizing, planning, and teaching science are given. The appendix contains bibliographies of professional books, sources of scientific equipment and supplies, and many other helpful lists.

ADDRESSES OF PUBLISHERS

Abelard-Schuman	Abelard-Schuman, Ltd., 6 W. 57th St., New York, N.Y. 10019
Allyn and Bacon	Allyn and Bacon, Inc., 150 Tremont St., Boston, Mass. 02111
Atheneum	Atheneum Publishers, 162 E. 38th St., New York, N.Y. 10016
Benefic Press	Benefic Press, 1900 N. Narragensett, Chicago, Ill. 60639
Bobbs-Merrill	The Bobbs-Merrill Company, Inc., 4300 W. 62nd St., Indianapolis, Ind. 46206
Childrens Press	Childrens Press, Inc., Jackson Blvd. & Racine Ave., Chicago, Ill. 60607
Creative Educational Society	Creative Educational Society, Inc., Mankato, Minnesota 56001
Dodd, Mead	Dodd, Mead & Co., 432 Park Ave. So., New York, N.Y. 10016
Doubleday	Doubleday & Co., Inc., 575 Madison Ave., New York, N.Y. 10022
F. A. Owen	F. A. Owen Publishing Co., Dansville, N.Y.
Franklin Watts	Franklin Watts, Inc., 575 Lexington Ave., New York, N.Y. 10022
Garrard Press	Garrard Publishing Co., 1607 Market St., Champaign, Ill. 61821
Harcourt, Brace & World	Harcourt, Brace & World, Inc., 757 Third Ave., New York, N.Y. 10017
Harvey House	Harvey House, Inc., Irvington-on-Hudson, N.Y. 10533
Henry Z. Walck	Henry Z. Walck, Inc., 19 Union Sq. W., New York, N.Y. 10003
Holt	Holt, Rinehart & Winston, Inc., 383 Madison Ave., New York, N.Y. 10017
Houghton Mifflin	Houghton Mifflin Co., 2 Park St., Boston, Mass. 02107
John Day	The John Day Co., Inc., 200 Madison Ave., New York, N.Y. 10016

Knopf	Alfred A. Knopf, Inc., 501 Madison Ave., New York, N.Y. 10022
Lantern Press	Lantern Press, Inc., 257 Park Ave. So., New York, N.Y. 10010
Lippincott	J. B. Lippincott Co., East Washington Sq., Philadelphia, Pa. 19105
McGraw-Hill	McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York, N.Y. 10036
Melmont	Melmont Publishers, Inc., Jackson Blvd. & Racine Ave., Chicago, Ill. 60607
Merrill	Charles E. Merrill Books, Inc., 1300 Alum Creek Dr., Columbus, Ohio 43216
Messner	Julian Messner, Inc., 8 W. 40th St., New York, N.Y. 10018
Morrow	William Morrow & Co., Inc., 425 Park Ave. So., New York, N.Y. 10016
Prentice-Hall	Prentice-Hall, Inc., Englewood Cliffs, N.J. 07631
Putman's	G. P. Putnam's Sons, 200 Madison Ave., New York, N.Y. 10016
Random House	Random House, Inc., 457 Madison Ave., New York, N.Y. 10022
Scholastic Book Services	Scholastic Book Services, 904 Sylvan Ave., Englewood Cliffs, N.J. 07631
Scribner's	Charles Scribner's Sons, 595 Fifth Ave., New York, N.Y. 10017
Singer	L. W. Singer Co., Inc., 249 W. Erie Blvd., Syracuse, N.Y. 13202
TAB Books, Inc.	See Scholastic Book Services
Time, Inc.	Time, Inc., Book Division, Time-Life Bldg., Rockefeller Center, New York, N.Y. 10020
Viking	The Viking Press, 625 Madison Ave., New York, N.Y. 10022
Whitman	Whitman Publishing Co., 1220 Mound Ave., Racine, Wisconsin 53404
World Publishing	World Publishing Co., 2231 W. 110th St., Cleveland, Ohio 44102

ADDRESSES OF AUDIOVISUAL SUPPLIERS

The teaching suggestions for each unit of this Teacher's Edition list a number of films and filmstrips for classroom showing. Orders or further requests for information should be addressed to the following distributors or suppliers whose names are given in abbreviated form at the left.

Cenco	Cenco Educational Films, 1700 Irving Park Rd., Chicago, Ill. 60613
E.B.F.	Encyclopaedia Brittanica Films, Inc., 1150 Wilmette Ave., Wilmette, Ill. 60091
E.F.D.	Educational Films Division, John Colburn Associates, 1122 Central Ave., Wilmette, Ill. 60091
F.A.	Film Associates of California, 10521 Santa Monica Blvd., Los Angeles, California 90025
Jam Handy	Jam Handy Organization, 2821 E. Grand Ave., Detroit, Michigan 48211
McGraw-Hill	McGraw-Hill Publishing Co., Text Film Dept., 330 W. 42nd St., New York, N.Y. 10036
S.V.E.	Society for Visual Education, Inc., 1345 Diversey Parkway, Chicago, Ill. 60614

Answer Key to TEACHING TESTS

UNIT ONE

1. c
2. b
3. d
4. c
5. b
6. c
7. d
8. b
9. c
10. a
11. sedimentary rock
12. metamorphic rock
13. granite
14. limestone
15. slate
16. c
17. a
18. b
19. d
20. c

UNIT TWO

1. a
2. b
3. a
4. b
5. b
6. b
7. a
8. a
9. b
10. d
11. oxygen
12. silicon dioxide
13. nitrogen
14. iron
15. calcium carbonate
16. d
17. c
18. a
19. a
20. b

UNIT THREE

1. b
2. b
3. a
4. a
5. a
6. c
7. b
8. c
9. a
10. d
11. gravity
12. thrust
13. unbalanced force
14. inertia
15. balanced force
16. b
17. a
18. a
19. c
20. a

UNIT FOUR

1. cell membrane
2. nucleus
3. cytoplasm
4. chloroplast
5. cell wall
6. b
7. a
8. b
9. c
10. d
11. protoplasm
12. DNA
13. starch
14. glucose
15. ATP
16. d
17. b
18. a
19. d
20. c

UNIT FIVE

1. a
2. b
3. h
4. d
5. c
6. a
7. b
8. d
9. a
10. c
11. arm
12. lungs
13. spinal cord
14. small intestine
15. backbone
16. b
17. d
18. c
19. a
20. b

UNIT SIX

1. b
2. b
3. a
4. a
5. a
6. d
7. c
8. c
9. a
10. b
11. chlorophyll
12. sugar
13. carbon dioxide
14. water
15. minerals
16. c
17. a
18. c
19. b
20. d

UNIT SEVEN

1. a
2. a
3. b
4. b
5. f
6. d
7. b
8. a
9. a
10. c
11. prism
12. mirror
13. spectroscope
14. mirror
15. light meter
16. d
17. c
18. d
19. c
20. c

UNIT EIGHT

1. dinosaur
2. platypus
3. mammoth
4. trilobite
5. ostracoderm
6. d
7. c
8. c
9. b
10. a
11. reptiles
12. fish
13. amphibians
14. reptiles
15. mammals
16. a
17. d
18. b
19. d
20. c

5

Concepts in SCIENCE

PAUL F. BRANDWEIN

ELIZABETH K. COOPER

PAUL E. BLACKWOOD

ELIZABETH B. HONE

HARCOURT, BRACE & WORLD, INC.
New York Chicago San Francisco Atlanta Dallas

to the general structure of the Earth. Exploration of caves resulting in archeological finds and discovery of natural phenomena is described. (Easy—with interesting content for average and advanced readers)

All About the Planet Earth by Patricia Lauber, Random House, 1962. The picture of the planet Earth, as revised by International Geophysical Year findings, is portrayed by interesting narrative photographs, drawings, and diagrams. Development of new theories is unfolded as the reader takes part in the work of the IGY scientists. (Average)

Our Earth by Frederick H. Pough, Whitman, 1961. Much factual information about the Earth, from its inner core to the atmosphere. Superficial treatment of theories on shape, structure, composition, and age of the Earth. (Average)

The Earth's Story by Gerald and Rose Wyler Ames, Creative Educational Society, 1962; in cooperation with the American Museum of Natural History; from the Creative Science series. An excellent reference for average readers using the table of contents and index for location of assigned topics. Interesting narrative and many photographs describe major changes which occur on and within the Earth. The evolutionary development of the Earth is emphasized. (Advanced)

Rocks All Around Us by Anne Terry White, Random House, 1959. Ancient formation and present-day use of rocks are described in relationship. The changes rocks undergo are briefly described. (Easy)

°*The Story of Archeology in the Americas* by Mary Elting and Franklin Folsom, Harvey House, 1960. Description of the action of the forces of nature is interwoven with the story of archeological finds in many locations in North, Central, and South America. To extend study, archeological sites, museums, and organizations are listed by locations in the United States. Children and teachers will be tempted to read and refer to this book again and again. (Average, but tempting to slower readers)

The Rock Hounds by Donald Nasca and Glenn Sprague, F. A. Owen, 1964. A narrative story of the rock-hound activities of two boys, interwoven with information about rocks, their formation, identification, and mineral content. A brief but useful introduction to rock collecting as a hobby. (Easy, but interesting content for average readers)

°*The Soil Story* by Helen Heffernan and George Shaftel, L. W. Singer, 1963. From the Man Improves His World series. Average readers will find the book valuable as a reference for study of assigned sections or topics. The importance and need for preservation of soil are detailed in both a fictional story and a wealth of facts on soil use and conservation around the world. Properties of soil are described in concise physical and chemical terms. A glossary and index will help pupils understand and locate special topics. (Advanced)

Wonders of Rocks and Minerals by Richard M. Pearl, Dodd, Mead, 1961. Basic information about rocks and rock collection, with appeal to beginning hobbyists and children seeking science information. Includes sections on rock formation and structure, minerals, crystals, precious stones, metals, and supplies and procedures for collecting. (Average)

°*Volcanoes and Earthquakes* by Robert Irving, Knopf, 1962. The scientific facts and physical evidences of volcanoes and earthquakes are concisely described. True-story accounts of ancient and recent occurrences of these phenomena, from the destruction of Pompeii and Herculaneum to the 1960 earthquake in Chile, relate these earth movements to both sudden and long-time building up and wearing down of the Earth. (Average)

Volcano! by Walter Buehr, Morrow, 1962. Description of historic eruptions. Excellent diagrams and illustrations help pupils to understand both cause and effect of volcanoes. Reader curiosity and excitement are stimulated by the brief but interesting presentation of scientific fact and true-to-life accounts. (Average)

Classroom Laboratory – Assembling and Organizin Materials

In addition to planning in advance for films, filmstrips, and books for yourself and the science reading table, it is well to check beforehand on materials you have available for demonstrations and investigations. Throughout this Teacher's Edition, marginal notations are given under the heading "Equipment and Materials" wherever an investigation is suggested to supplement the work of the child's textbook. These materials are usually readily available in the classroom or easily obtainable by pupils from local or home resources.

The child's textbook includes a number of investigations, indicated by a blue tint on the pages on which they occur. The equipment needed is listed at the beginning of the investigation. The number of items you will need to have on hand depends on whether you plan to use the investigation as a demonstration or to have children work individually or in groups. For efficient investigating, materials should be gathered in advance or ordered, if necessary, from the school supply room.

As more fully described on page F–17, a set of laboratory equipment and materials, *Classroom Laboratory 5,* to accompany *Concepts in Science 5,* is available from the publisher. The materials are conveniently packaged so that six groups of pupils may, as a rule, work on an investigation at one time. An exception is that a few items, such as alcohol lamps, are provided singly. Most of the investigations in *Concepts in Science 5* can be performed by using these materials, which are the same or similar to those suggested on the investigation pages. Notations are given in the margin of this Teacher's Edition for each investigation. If you have *Classroom Laboratory 5,* it is useful to refer to Part II of the Teacher's Manual included in it. You will find suggestions for carrying out the textbook investigations and other investigations that extend the concepts.

▶ INTRODUCING THE UNIT

What does it feel like to be in a mine tunnel or a cave? What would you see on the way if you could dig through to China? Why is a deep mine a kind of window into the unexplored? Why do deep mines require air conditioning more for cooling than for ventilation? What can be

Unit Six: GREEN CELLS AS BUILDING BLOCKS 226

1. Joan Investigates, *228* · 2. The Importance of Light, *233* · 3. The Lonely Green Plant, *237* · 4. We Seal in a Fish—And a Cow, *242* · 5. The Green Plants That Saved the Limeys, *246* · 6. Are You Sealed In? *248* · 7. Cells That Built Our Fuel Supplies, *252* · 8. Cells That Make Clothing, *257* · 9. The Main Concept: The Sun's Energy Captured, *261*

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Unit Seven: BUILDING BLOCKS OF THE STARS 270

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Unit Eight: STORIES IN THE EARTH 304

1. Bones and Their Meaning, *308* · 2. Only Sixty Million Years Ago, *312* · 3. Life in the Ancient Waters, *317* · 4. The First Step on Land, *323* · 5. Up to Now, *330* · 6. The Main Concept: The Story in the Earth, *336*

A NEW VIEW OF CHANGE 342

ON YOUR OWN:
PROBING THE EARTH'S CRUST 346

KEY CONCEPT WORDS:
A BEGINNING VOCABULARY FOR SCIENCE 359

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Unit One

THE EARTH—INSIDE AND OUT

(*Text pages 2–49*)

UNIT CONCEPT

Bodies in space, as well as their matter and energy, are in constant change.

The child begins his study of the changing universe by investigating the forces at work that are continually changing his familiar Earth environment.

A VIEW OF THE UNIT

A Preview of the Concepts

The quiet, solid Earth is really neither so quiet nor so solid. The forces of weathering and upbuilding are at work even now, as they were early in the history of the Earth.

Just as astronomers have found ways to study stars across space, geologists have discovered means to study the interior of the Earth, far deeper than the deepest mines or oil wells.

The tremendous force which pushes up volcanoes and entire mountain ranges is the result, in part, of heat caused by the slow breakdown of radioactive elements in the Earth's crust.

The variety of elements in the Earth, whether at the surface after being exposed by weathering or brought from within the Earth by vulcanism, are a treasure-house of materials for man's use.

The unit begins with the true story of Jimmy Ruhle, a thirteen-year-old boy, who found some fossil bones. How did his friend, Dr. Richards, recognize the animal and how did he know when it lived? Children arrive at some answers to these questions as they investigate how a mountain is broken down and how the land is built up. To understand why fossils may be found in ancient sediments deep under other rocks, children investigate the Earth inside as well as out. They gain a view of the Earth in its formative stages, before life existed. They gain some understanding of why rocks are so varied and often so difficult to identify. They grow in appreciation of the rich variety of useful substances under their feet.

Using Local Resources

Many children up to and through the fifth grade are inveterate collectors. Often their collections include rocks, depending to some extent on parents' hobbies and where the family lives and travels. Fossils arouse children's wonder. Pictures and stories of volcanoes and earthquakes excite their interest. Utilizing these persistent and characteristic interests of fifth-grade children, the text unit challenges children with the most recent thinking of geophysicists. These ideas are pitched at the child's level and clearly unified by the underlying theme of change. The child—a collector at first—is given opportunity to observe more carefully, *to seek orderly explanations (concepts)* which give meaning to his observations, and to *test his observations* by laboratory work. In so doing he hypothesizes, designs investigations, predicts, and—most of all—attempts to put to the test his assertions about the way the world works. The child, in his way, acts as a scientist does.

In setting the stage for this unit, the teacher may early discover that some children and parents collect rocks, minerals, and the like as a hobby. They may be invited to bring their collections or to serve as resource persons on the subject. Relating local rocks to a road map of your state is also always of interest.

A neighboring supplier of building materials can offer a wealth of samples of earth substances. A tombstone maker is a good source of sample rock chips. Soil survey maps, geological maps, contour maps, and travel folders showing volcanoes (Japan, Hawaii, Mexico) add interest.

SUPPLEMENTARY AIDS

Films

All the films listed below are in color. In order to have them available at the time you wish to show them, it is advisable to order them well in advance or to reserve them on loan from the supplier. The names and addresses of distributors of films and filmstrips, listed here by abbreviation, are given on page F–25. All films are in full color. Following each is a rating of the approximate range of content and difficulty. Those that are rated "Primary" are, in general, quite easy to understand while those with an "Intermediate" rating are about right for the grade level.

Birth and Death of Mountains (12½ min.), F.A. Although mountains appear permanent, they are ever changing. Water, wind, and ice destroy mountains. At the same time, underground forces are continually at work building up mountains. (Intermediate)

Earthquakes and Volcanoes (14 min.), F.A. Presents the causes of both earthquakes and volcanoes and the relationship between them. Illustrate faults, volcanic eruptions, and other unstable conditions of the Earth. (Intermediate)

Oceanography: Science of the Sea (11 min.), F.A. Oceanographers use instruments to explore the ocean waters, the sea floor, and Earth's interior beneath the floor. Sediments from the ocean floor provide clues to the history of living things. (Intermediate)

What's Under the Ocean? (14 min.), F.A. Scientists study the ocean in special craft, such as a bathyscaph, and map vast areas of ocean floor. (Intermediate)

What's Inside the Earth? (14 min.), F.A. Explores the interior of the Earth, indicating and illustrating the methods men use to determine Earth's structure. (Intermediate)

Our Earth (12 min.), Cenco, 1963. Earth is made of a core, a mantle, and the crust on which we live. Explains the three kinds of rocks. This film is good for beginning of study of Earth's crust. (Primary, Intermediate)

Filmstrips

All of the filmstrips listed below are in color and rated as excellent.

Changing the Face of the Earth (42 frames), S.V.E., 1962. Dramatizes the constant struggle between land-building and land-eroding forces. Man makes changes in Earth's crust by building dams and canals and by mining; but earthquakes, volcanoes, wind, and water also cause changes. (Intermediate)

Wind and Waves (42 frames), S.V.E., 1962. Describes the action of wind in carving rocks, forming dunes, depositing dust. Shows how waves and pebbles shape coastlines and how sediment from land causes new land to be formed on the ocean floor. (Intermediate)

Volcanoes and Earthquakes (40 frames), S.V.E., 1962. Pictures a cross-section of a volcano and explains how lava may help in forming a mountain—many islands are tops of volcanoes. Explains how earthquakes are caused by movement of blocks of rock along faults. Use of seismograph. (Intermediate)

Mountains (46 frames), S.V.E., 1962. Shows how mountains are formed and arranged into chains, how they appear and disappear, how they reveal the history of the Earth. (Intermediate)

The Earth's Crust (43 frames), S.V.E., 1962. Examines Earth's inner layers and outer crust. Explains magma and formation of igneous, sedimentary, and metamorphic rocks. (Intermediate)

The Earth's Diary (47 frames), S.V.E., 1962. Shows how the shape and size of continents have undergone changes, how ice sheets and lava have left traces. Man reads history through rock formations and fossils. (Intermediate)

Work of Ground Water (47 frames), S.V.E., 1957. Explains water tables, caves, geysers, and hot springs; how ground water affects mineral deposits; stalactites, stalagmites. (Intermediate)

Work of Internal Forces (50 frames), S.V.E., 1957. Shows how the surface of Earth is constantly being changed by internal forces, faulting, folding, formation of plateaus, and volcanic activity. (Intermediate)

Our Earth: Land, Water, and Air (61 frames, with sound), S.V.E., 1965. Colored photographs show that the Earth is made of oceans, rivers, lakes, ponds, swamps, mountains, plains, and air. Deep layers of rock surround the iron and nickel core of Earth. (Intermediate)

Science Reading Table

Having elementary science books on a reading table in one part of the room for free reading investigation is a stimulus to interest in science. Many titles are available and more are continually being published. The books below have been found useful for this unit; those starred are especially recommended. Following each title appears a rating of the reading level in relation to the content and concepts of the child's textbook. Names and addresses of the publishers are on page F–24.

About Caves by Terry Shannon, Melmont, 1962. The story of how wind, water, volcanoes, earthquakes, and frost have helped to make caves. Relates them learned through a telescope about the origin and early history of Earth? Even though no one has gone as deep into the Earth as the mantle rock, how do we know about its temperature and what it is like? How do we know about Earth's deep core? Does it seem reasonable to believe molten rock could be "piped" 4,000 miles from the hot core? If not, what causes volcanic eruptions? Why do earthquakes occur and volcanoes often exist along or near a mountainous coastline?

Depending upon the readiness of your group, you may find it challenging to display such questions individually on strips of tagboard or discarded Venetian blinds. Children may enjoy preparing them. Wax crayon marks on the blind strips can be removed at will. Encourage holding puzzling questions for later reconsideration and review. It is not necessary to introduce all questions at the beginning; it is better and more desirable to have the children raise the questions (and develop hypotheses) as a basis for their own investigations and discoveries.

(Text pages 4–10)

SUBCONCEPT

Weathering and erosion break down the hardest rocks.

Processes emphasized

Observation
Field study
Investigation
Hypothesizing
Consulting and reporting
Inventing models

Equipment and Materials

. . . carpenter's saw
. . . hack saw
. . . coping saw
. . . map
. . . seedling, young shrub, or tree (potted)
. . . lichen or moss

Section 1: BREAKING DOWN A MOUNTAIN

Children explore the forces that are constantly changing the land forms around them.

Introducing the Concept

What can you do with a saw? Utilize one or more carpenter's saws to help children conclude that saws cut through materials. Draw attention to the saw-blade material and then, by contrast, inquire if saws could be made of water instead of steel. Can you point to saws made of water on a map of your state or country? Often such saws of water are shown in blue. As it begins to dawn upon the children that you are referring to rivers as saws, ask if plants would make good saws? Examples of lichens, mosses, or other "rock breakers" would be desirable, but a potted tree, shrub, or seedling would suffice.

What kind of tools were used to sculpture such rock formations as Natural Bridge, or Bryce or Zion Canyons? Must you go far to see forces of erosion at work? What examples, perhaps in miniature, can you see from your window or sidewalk? Just how does a saw of water work?

These questions lead directly to the investigation on page 5—after the children have read the opening paragraphs of the section.

Changes in heat are a cause of weathering.

Developing the Concept

What is weathering? Print on the board the word WEATHER. What does it mean? Most children will mention rain, snow, clouds, and other meteorological effects. After a few moments' discussion, add the suffix, –ING. *Now* what does the word mean? Without trying to reach any definite conclusions, ask the children to help you compile a list of major land forms: bodies of water (oceans, lakes, rivers), islands, continents, mountains, valleys, plains, etc.

Which forms can you see from your school? From your community? Even from the classroom windows, children should be able to see examples of weathering; e.g., oxidation (rusting), weathering of wood, staining of stone and masonry, etc.

What is erosion? Now is a good time for a ten- to twenty-minute schoolground study trip. Perhaps you could see some miniature land forms very close to you. How can land forms change? Encourage children to look for illustrations of how water eats away Earth's surface: gullies on slopes, fanning out of sediment washing onto a sidewalk, meandering streamlets after a rain. How do these compare with such forms as canyons, valleys, deltas, river beds?

Wind and water are agents of erosion.

Washing down a model mountain is another way of illustrating how water eats away Earth's surface. You will not want to build your mountain in an indoor sand table as is often suggested; wet sand and soil are heavy and troublesome to clean out afterwards. It is much easier and less messy to model your mountain in a large shallow carton set in a corner of the playground. Later you can pull the wet carton apart and scatter or rake away the soil.

Equipment and Materials

. . . large shallow carton
. . . various soils
. . . grass sod

Without divulging your plan, ask each child who can to bring a quart or more of soil from home. To secure a variety of soils, it may be helpful to discuss briefly soil types, such as sand, loam, gravel, clay, and humus.

When the mountain is modeled to everyone's satisfaction, hose it with a fine spray. Delegate questions such as the following to different observers:

Which soil particles move first? Which last? What difference do you see when we use a coarse spray? Where do gullies start and how do they grow? What effect does the slope have on erosion? Do plant roots (if a square of sod is used) reduce erosion? How can we slow the effects of running water? (e.g., debris, wattling, etc.)

For further detail, government agencies concerned with soil conservation (e.g., state and national soil conservation agents, county farm-bureau agents) are usually able to provide a wealth of illustrated references on soil erosion and soil conservation. Certain of the annual *Yearbooks* of the United States Department of Agriculture, available in many libraries, are useful references on soil conservation.

How do plants break up rocks? Fill a small plastic container, such as that used in the investigation (text page 5), with dry lima beans or peas. Fill with water to the very brim. Cap tightly, seal, and *set in a pan* in the refrigerator. By the next day the container will have split open and the seeds spread all over the pan. Why? Children will wish to compare these seeds with dry ones (the control) and note the swelling of the moist seeds. Discuss also the text paragraphs headed by "Plants at Work."

Plants are also agents of erosion.

Equipment and Materials

. . . small plastic container
. . . dry lima beans or peas
. . . shallow pan
(See also the Teacher's Manual for *Classroom Laboratory 5.*)

Extending the Concept

Why do we call the lowly lichen a rock-breaker? Children with an interest in chemistry may be stimulated to do reference work and report on the chemical reaction (in connection with lichens—text page 8) in which weak carbonic acid (made from water and carbon dioxide) eats away at the rocks on which lichens grow. Thus, they design their own investigation (with controls).

Children reading about lichens will probably discover that lichens might be termed "mountain climbers" and "arctic explorers." Lichens grow higher up on mountains than any other plants. Growing in the tiniest fissures of the rocks and with no visible soil, lichens, over the years, help to crumble the rocks and make soil for mosses.

Rock weathering due to mosses creates soil and moisture which permit the beautiful flowers and other alpine plants of timberline to gain a foothold. Thus, we see the role of lichens as the first stage in plant succession, which could be said to culminate in those extra-size plants we call trees.

Is there weathering on the Moon? Are there winds, water, or plants on the Moon? Children already interested in space could be challenged to further investigation. An organized, illustrated report could be presented to the class.

(*Text pages 9–10*)

Reviewing the Concept

Questions at the end of each section in the child's textbook permit him a quick review of concepts and supporting ideas. Answers are provided on the teacher's pages. Only one correct answer is possible under "Before You Go On." A suggested answer is given for the questions under "Using What You Know"; other answers are possible depending on the child's experiences. No answers can be given for most of the other activities as they depend on the child's own investigations.

Before You Go On. A. 1. a 2. b 3. a 4. b

Using What You Know. 1. Plowing around the hillside saves both water and soil. Water sinks into the ground or runs off slowly, carrying few soil particles. 2. They will hold back the flow of water and prevent gully erosion. 3. An old mountain has a rounded top; a young mountain has jagged peaks.

(*Text pages 11–17*)

SUBCONCEPT

Weathering and erosion help build up new land.

Section 2: BUILDING UP THE LAND

Children begin to see that wearing down of rock and soil is balanced by building up of new land by layers of sediment—bits of rock, soil particles, and remains of living things.

Equipment and Materials

. . . a globe

Introducing the Concept

Look at a model of the Earth (a globe). What do you see? (Land and water.) If you turn the globe, do you see more land or more water?

(More water.) How much water? ($\frac{3}{4}$ to $\frac{7}{8}$ is the fraction usually given.) What body in space would our Earth resemble if its bodies of water were dry? (The Moon.)

Processes emphasized

Observation
Investigation
Field study
Hypothesizing
Model building (invention)
Theorizing
Predicting

Does the globe show deep places in the ocean? (The Marianas Trench near the Philippines.) Does it show mountain ranges? (The Atlantic Ridge—thirty miles wide between Europe and the Atlantic Coast.)

People who study land are geographers. What do you think we call people who study and map the ocean floor? (Oceanographers.) Encourage the collection of news items and articles on oceanography. What equipment can you name that is used for underwater exploration? (Aqualungs, divers' helmets.) What kind of equipment and records do oceanographers use?

Why do geographers and oceanographers study the land and the ocean floor? What evidence of erosion and weathering do they find?

After the children have suggested answers to these questions, give them an opportunity to read the opening pages of the section and to build the model sediment layers.

Developing the Concept

The action of water sorts out soil particles, which settle in layers and eventually form sedimentary rocks.

How does sediment settle? Why did soil samples in the investigation (text page 15) settle out in layers? (Because of the sorting action of water.) Does this always happen? To be sure, let's shake our containers again and see if the sediments fall out in the same way again. While waiting for the sediments to settle, recall from Section 1 how the water sorted out soil particles on the playground, along a stream, or on the coast.

Equipment and Materials

. . . pail
. . . soil

(See also text page 15 and the Teacher's Manual for *Classroom Laboratory 5*.)

The finer particles travel faster and farther, the heavier tend to drop out earlier. Why? Does gravitation pull harder on light or heavy particles? (Water holds the smaller particles up.) This sorting action helps to explain layers of sediment.

What do you think sticks soil particles together to make sedimentary rock layers? Perhaps lifting a pailful of soil will give you an idea. (Weight—pressure—pushes them together.)

By using discarded milk cartons and varying the amounts of cement, sand, and plaster that are mixed, children can make a variety of "synthetic" sedimentary rocks, such as shale and limestone conglomerate. (See *A Sourcebook for Elementary Science*, pages 115–16.)

Children add to their understanding of how sedimentary rocks are formed.

Where are fossils found? What is a fossil? Initiate a discussion leading to the conclusion that fossils are usually imprints (e.g., fossil shells) or petrifaction (e.g., petrified wood). Only rarely do we find actual remains preserved, as in ice or asphalt. Then: Knowing what you do about how sediments are laid down, can you see why geologists look for fossils in sedimentary rocks? (As plants and animals died, they were covered with fine layers of mud which hardened into rock.)

Equipment and Materials

. . . pictures of birds or mammals, reptiles, insects, tree ferns, shells

Here is a stack of four books. Imagine that each book represents rock layers laid down during a different period in geologic time. Which rocks are at the bottom? (The oldest.) The top? (The newest.) Into each book a picture or sketch of an animal which might have lived then has been tucked away. Can you predict which picture we will find in the top book? (Bird or mammal.) The bottom? (Shells.) The upper-middle? (Modern reptile or dinosaur.) Lower-middle? (Insect or fern.) Let's check our predictions. If the children have not finished reading the section, encourage them to verify their hypotheses and predictions by doing so now.

Extending the Concept

Can you read a ditch? Can you "read" the sedimentary layers in a ditch? The next time you see men or power shovels digging a deep trench, look at the layers of soil. Do some layers have tiny, close-packed particles? (These are probably clay.) Are some layers sandy? Do some have bits of rock? From what you know about sediments, what do these layers tell you? (Water, over many years, has been at work sorting out sediment from the wearing down of rocks.)

Equipment and Materials

... rock samples
... sandpaper
... paper cup
... glue

Making soil from eroded rock. Try making your own soil from different kinds of sedimentary rocks. A builders' supply firm often has small samples. Sandpaper the samples or rub them against one another. Now try putting the sandstone back together again. In a paper cup, mix the dry sand particles with glue or paste and allow to dry. You should still be able to see the rock crystals. In doing this, children have opportunity to engage in developing models, a constant activity of the scientist. Try the same procedure with other rocks. Look for kinds of sedimentary rocks in buildings, streets, and bridges.

What is used for underwater exploration? Submarine geographers at work use aqualungs, divers' helmets, submarines, and bathyscaphs.

What is there in any of these which is similar to vehicles used for space exploration? Challenge one group or team to think of ways of demonstrating what makes the bathyscaph float (e.g., mix kerosene or kitchen oil with colored water; the oil comes to the top).

Another team might construct or demonstrate a model submarine. (See *A Sourcebook for Elementary Science,* page 189.)

(*Text pages 16–17*)

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. a 4. b

Using What You Know. 1. A is oldest; D is youngest because first sediments will be on bottom, last on top. 2. Rushing river will bring coarse sediments; slow-moving river the finer sediments. Fine sediment takes longer to settle out.

(*Text pages 18–25*)

SUBCONCEPT
The Earth is in constant change.

Section 3: WE BUILD AN "EARTH"

From a study of waves in the Earth, children learn that the matter of the Earth is in continual motion.

Introducing the Concept

What can a model teach you? Most fifth-grade groups include children who build model planes or cars. If appropriate, encourage these children to bring a model to show as they respond to the question, "Why do scientists build models?" Model dinosaurs or, better, a paper model of the DNA molecule can be secured at most hobby stores.

Why does a scientist build models of things he discovers? What would make a good model of Earth? How solid is the solid Earth? How do you go about exploring deep inside the Earth?

Developing the Concept

A cross-section view of Earth. To select the most appropriate model and to gain a better understanding of Earth's interior, plan for the children to work in teams, making the following cross-section diagram of Earth.

If we use a scale of 1″ = 1,000 miles, how far across must the outside circle be? (8″) The crustal rocks are believed to range from 2 to 8 miles in thickness under the oceans to a 40-mile thickness under major mountain chains. Since the crust averages only 1/100 of the Earth's radius, or distance to the center, it may be shown by a colored line at the edge of the 8″ circle.

Using the same scale of 1″ = 1,000 miles, the children could cut a $4\frac{1}{2}''$ circle of another color of construction paper to represent the core of the Earth, believed to be about 4,400 miles in diameter, and center it in the 8″ circle. The area outside the edge of this inner circle represents mantle rock, believed to extend to a depth of about 1,800 miles below the crust. Even 10 miles down the pressure is enormous—about 4,600 tons per square foot. Try to imagine the weight and pressure of 2,600 automobiles stacked on a half dollar—about 1 square inch.

Evidence suggests mantle rock is probably hotter than 5,000° F. The enormous heat and pressure combine to make this very heavy rock bend, twist, and flow like dough, or like asphalt on a summer day.

The Earth's inner-core rocks are believed to be about 3,100 miles from the crust, or beginning about 900 miles from the center. Invite the children's designs for making models of the core, which is about 1,800 miles in diameter and is probably composed of nickel iron. Estimates of the temperature of the core range from 4,000° F. to as much as 36,000° F.

In preparation for the class diagrams or to review, it may be useful to make a wall-sized, cross-sectional representation of the Earth. A scale of 1″ = 100 miles is simplest. If wall space does not permit an 80″ circle, try a longitudinal wall-hanging showing segments. The circles or segments are effective in different colors. The core section, if you use a segment, should have a radius of about 22″; the mantle, 18″; the crust, $\frac{1}{3}''$; total radius, 40″. Reading of the text (pages 21–23) where models of the Earth are discussed, will be useful.

Equipment and Materials

. . . model plane
. . . model of DNA molecule

Children learn about Earth's interior by making a diagrammatic model.

Processes emphasized

Investigation
Model building (invention)
Measurement
Hypothesizing
Theorizing
Inferring
Library research

Equipment and Materials

. . . scissors
. . . draftsman's compasses
. . . 2 to 3 colors of construction paper

Children relate the Earth's structure to a three-dimensional model, an activity similar to the scientist's.

Equipment and Materials

- . . . orange
- . . . baseball
- . . . globe

A baseball model of the Earth. You remember why scientists build models of something they are studying. If we could cut each of these models in half (pointing them out), what information from the diagram would help you decide which object makes the best model of Earth?

The baseball is the most realistic model, for the thinness of its outer covering may remind you of the Earth's thin and uneven crust. Inside a baseball are yards and yards of cord. These layers of cord are comparable to the Earth's plastic mantle. The cord winding, which gives the baseball its rigid resilience, is wound over a hard rubber layer which covers a core of cork. The rubber might be compared to the outer core of rock, which begins at a depth of 1,800 miles and extends another 1,300 miles from the surface.

Children discover that waves are used to study the Earth's structure.

Equipment and Materials

- . . . gallon jar or aquarium
- . . . pebbles

Are there waves in the Earth? What is a wave? Fill a gallon jar or aquarium half full of colored water. Drop in a small pebble and ask two observers standing close to the jar to observe what they see. Accept their observations without evaluation. Repeat with other close observers until they see that concentric ripples or waves are created by the motion of the pebble. The children may infer that these are waves of motion set up by the energy of the moving pebble. Do waves of motion travel only in water?

Some time should be spent in reading and discussing the text so that children gain an initial understanding of earthquakes and earthquake belts. The model on text page 22 gives them further insight into the plasticity of the mantle rock below the crust. If children are intensely interested, as they are likely to be, the lesson may be extended by any of the following activities.

Extending the Concept

Windows into the Earth. When you bake something, you watch it through the window in the oven door. What are the "windows" through which scientists have learned about Earth's interior?

Children who enjoy reading may wish to enlist the librarian's help to find out more about one kind of window—mines and oil wells. For example, the deepest mines in the world—the diamond mines of South Africa—penetrate the crust to a depth of only 2 miles. At these depths the miners must have air cooling in order to work. The deepest oil wells have penetrated only 5 miles. On your large cross-section of the Earth—1″ representing 100 miles—how deep would the mine and the well be? Could you show it on the model? How deep has man gone into the ocean? The newest window into the Earth is Project Moho or Mohole. How does the project get its name? How is the project being carried on?

Equipment and Materials

- . . . cookie sheet or roast pan
- . . . damp sand or soil
- . . . plastic bag

Why do earthquakes cause such damage? Some children may develop a model of an earthquake by setting up the following "miniaturized" version of what happens to crustal sediments and surface objects during an earthquake.

Spread a plastic vegetable bag on the bottom of a pan. Let the mouth of the bag hang over one end as shown. Cover the bag with a layer of damp soil or sand. Tamp the soil smooth. Set a few objects on the soil to represent buildings and other objects on the Earth's surface. Inflate the bag and observe the cracks in the surface. Some of the "buildings" will be toppled or shifted in the process.

What to do in case of earthquake. Encourage children who can do independent investigation to develop and present a playlet illustrating safety procedures in earthquake areas. Questions to be studied might be: How would you decide where or where not to buy a home in earthquake country? How can you demonstrate a seismic wave? (See *A Sourcebook for the Physical Sciences,* figure 4-9.)

A headline reads, "Aleutian Quake—Coast Alerted to Tidal Wave." Find out how tidal waves are related to earthquakes.

(Text pages 24–25)

Reviewing the Concept

Before You Go On. A. 1. b 2. b 3. b 4. b

Section 4: THE FURNACE IN THE EARTH

(Text pages 25–30)

SUBCONCEPT

Heat and pressure generated within the Earth result in changes of its surface.

Equipment and Materials

. . . percolator

Processes emphasized

Investigation
Model building
Observation
Hypothesizing
Theorizing
Reporting
Measurement
Prediction

Children investigate the source of the Earth's internal heat energy and how this energy exerts pressure on the Earth's crust, resulting in eruption of volcanoes.

Introducing the Concept

The children now have a notion of how changes take place on the Earth's surface by erosion and weathering of rocks and by the building of sedimentary rocks and their shifting under pressure. How else may the Earth change? In advance, fill a percolator with colored water and set it over heat with the top removed. Why does water spout from the "perking" percolator? (Heat makes the water molecules move faster; the pressure resulting from this rapid motion forces water up the central tube.) Actually, this is a good model of a geyser, a "water volcano." What heats the water in geysers and hot springs? Children infer that underground water in contact with heated rock spurts up through cracks. Why? (Rapidly moving molecules exert pressure.)

There is always interest in volcanoes. Some children who have seen motion pictures of a volcano in action can describe it. Or you can illustrate the discussion with photographs if any are readily available.

What makes a volcano erupt? How is a volcano like a "mountain in a hurry"? Where does the heat come from that can make rocks in the Earth hot enough to melt? How do volcanoes change the Earth?

Children may now be sufficiently stimulated to read as far as the heading "Inside an Atom" in their textbooks, or you may first wish to engage them in some of the following preliminary investigations.

Developing the Concept

Heat is one form of energy that causes motion of molecules—and of groups of molecules.

How energy makes matter move. Pound a length of metal pipe. Drive a nail into wood. Why do the metals get warm? What does pounding (a form of energy) do to the molecules in the pipe and the nails? (It makes them move faster.)

Equipment and Materials

... Pyrex beaker
... marking crayon or adhesive tape
... 220° F. thermometer

Can heat energy be used to make something move? Place water in a Pyrex beaker, carefully mark the water level with wax marking crayon or a bit of adhesive tape, and insert a thermometer. As the water starts to heat, what happens in the thermometer? (The liquid in it moves.) Continue heating the water. What happens to the water level in the pan? (It rises.) Why did the liquid rise in the thermometer and in the beaker? (The molecules are moving faster, causing them to take up more space.) You have probably seen the lid on a cooking pot rise as water is brought to a boil. Why? (The molecules are moving fast enough to create pressure and lift the lid.) How is this action like the percolator's? Like a volcano's?

Pressure causes matter to move.

Equipment and Materials

... clay soil
... plastic bag
... funnel

Modeling a volcano. Children can create a fair approximation of a volcano and lava flows by thinning clay soil with water until it flows like mud. Or you can demonstrate the actions. Fill a plastic vegetable bag with the mix and tie securely to the mouth of a funnel. Invert the funnel and press on the bag. By varying the consistency of the mix, children can see why some volcanoes erupt rather peaceably while others literally "blow their tops." The thicker mix tends to clog the vents and build up pressure. Something similar happens in real volcanoes as the molten magma cools in the chimney of a volcano, hardens, and plugs the vent.

Breaking up of radioactive atoms within the Earth releases enormous heat, creating tremendous pressure.

Equipment and Materials

... marbles
... plastic bag

Where does the Earth get its heat? You may wish to encourage the children to complete reading the section before they explore this question. How do atoms of certain substances break up and supply great amounts of heat? Suppose we place a number of marbles in this plastic bag to represent protons and neutrons in the nucleus of an atom. How can we show this nucleus breaking up, one particle at a time? If the children do not come up with the answer, cut a hole in the bag just large enough to let one marble through at a time. How does this model illustrate breaking up of radioactive atoms? When the nucleus of an atom gives off rays and particles, what form of energy is given up? (Heat.)

In review, what does heat do to molecules? If they have no place to go, what kind of force is built up? (Pressure.) Relate to the text discussion of natural breaking up of uranium and other radioactive atoms. Can you see how heat and pressure can be built up to melt rocks in the Earth when there are radioactive atoms? Can you now explain what makes volcanoes erupt?

Extending the Concept

Equipment and Materials

... frozen biscuit rolls

What makes the Earth sometimes crack open? Two packages of frozen biscuit rolls can be used to demonstrate the cracking of the Earth under internal pressure. Set one package on a table at room temperature and place the other over a radiator or hot water. Why do the biscuits in the heated package pop open faster? What causes the pressure inside the rolls? (Heat causes molecules of gases in the dough to move faster; the rolls expand, cracking the top surfaces.)

Equipment and Materials

. . . inverted funnel
. . . plastic bag

How do volcanoes change the Earth? Next time you go to the dentist ask him to show you the pumice powder he uses to clean your teeth. Pumice and other forms of lava are used in a variety of ways. To illustrate how pumice and other fine fragments (ash and pebbles) are ejected from a volcano to build up land, run puffed rice or other dry cereal through a blender. Place the powdered cereal in a plastic bag. If the bag is attached to the mouth of an inverted funnel and squeezed, the cereal fragments are realistically ejected from the nozzle in spurts of energy. The traditional chemical volcanoes have been known to cause accidents. A "puffed-rice" volcano is undeniably "childproof." Children get further experience in a fruitful activity of the scientist, the making of models to test concepts.

Where are earthquakes and volcanoes most frequent? Does every crack in the rocks in the Earth signal a volcano? You know that earthquakes happen daily around the world. Look for a map of earthquake belts of the world on a library reference map showing the location of the world's 400 *live* volcanoes. Why is there a similar pattern of distribution? The Pacific "ring of fire" (active volcanoes) may help you see why. Find a map showing the deepest part of the Pacific. Find one showing the mountain ranges on both sides of the Pacific. Where the ocean is deepest and the bordering mountains highest, the strain on the rock layers is bound to be greatest. Where there are weak places in the Earth's crust, there are earthquakes; and volcanoes may let out some of Earth's internal heat energy.

Checking encyclopedias under the heading *Earthquakes* should provide interesting material for special reports, stories, or playlets on famous earthquakes in history.

Equipment and Materials

. . . plastic sheets

Location of earthquake belts can be related to the study of geography. Some children may become interested in making plastic overlay maps to show earthquake zones. Children making these studies will move closer to the concept of crustal shift in areas where high mountains are close to ocean depths, creating strains and pressures.

(*Text pages 29–30*)

Reviewing the Concept

Before You Go On. A. 1. b 2. b 3. a 4. a

Using What You Know. 1. Mines, oil wells, volcanoes, hot springs. 2. It is no longer an atom; an atom consists of the particles tightly bound together. 3. Heat, wind, water, and chemical action will break lava down, building up the soil. Water in streams may carry it away and deposit it as sediment elsewhere.

(Text pages 31–35)

SUBCONCEPT

Pressures on and within the Earth uplift the Earth's crust.

Section 5: UP GOES A MOUNTAIN

Children move toward understanding that mountains are uplifted by heat energy accumulated from radioactive decay within the Earth, and that downward pressure on one region is compensated for by an upward shift in another.

Processes emphasized

- Investigation
- Model building
- Hypothesizing
- Theorizing
- Library research
- Field study
- Measurement

Equipment and Materials

- . . . stack of construction paper of several colors

Introducing the Concept

How are mountains pushed up? How would you use a stack of vari-colored construction paper to illustrate one way in which mountains are pushed up? As two children push from each end of the stack, the class can see the bending and folding of layers, much as sedimentary rocks are contorted and uplifted. Would you predict mountains would be uplifted quickly or slowly? How would volcanoes build up mountains? (Often quickly.)

What force is necessary to make both dough and mountains rise? (Pressure from increased motion of molecules.) How does a warm room help bread dough rise? Mt. McKinley, an uplifted mountain, the highest in North America, rises in Alaska. The Hawaiian Islands, formed by volcanic action, rise from the depths of the Pacific Ocean. The great cone of Mt. Etna, an active volcano in Sicily, towers above the Mediterranean.

What has pushed up the great mountains of the Earth? Why are fossils found above 10,000 feet in the Canadian Rockies?

Children relate inside and outside pressures to mountain building.

Equipment and Materials

- . . . plastic bag (or balloon)
- . . . shallow box, pan, or platter
- . . . clay soil
- . . . vegetable coloring
- . . . small bits of shell

Developing the Concept

Pressure of magma. Before or after the children read this section in their book, magma may be demonstrated. Spread a plastic bag or elongated balloon (deflated) flat on an inverted box or pan, with the mouth dangling free over one edge. Or use a shallow pan so that you can create a depression to represent the ocean floor. Spread clay soil, or detergent paste mixed with water and food colors, to form two or three thin layers. Small shells, or other materials children may suggest to represent fossils, may be placed in layers. Allow to dry. What happens when the bag or balloon is inflated? Encourage the children to develop hypotheses.

What kind of mountain building is this? (The pressure of magma pushing up and folding the rock layers.) What happens to the "fossils"? (They are raised up.) How does this indicate why fossils are sometimes found on hills or mountainsides?

Children relate pressures to the bending of rock layers.

What's inside a hill? Why do we have hills in some places and not in others? Children may be able to see folded layers of rock in the side of a cliff or quarry or along the side of a road cut through a hill. Often the layers tilt upward at one end and downward at the other, resembling the letter "A." Geologists call this kind of tilt an *anticline* ⌒. Formations that tilt downward at one end and upward at the other end are called *synclines* ⌣.

Where these conditions cannot be observed, use a stack of colored construction paper. Bend the stack to show anticlines and synclines. Layers of modeling clay may be bent and then sliced off at the top to show how erosion often truncates the tops of anticlines or synclines and exposes the core of a mountain. The upended red rocks in the Garden of the Gods (Colorado), and farther down into New Mexico, are remnants of sandstone layers gradually uplifted into a great arch, or anticline, over what are today the core rocks of the Cordillera—the backbone of the Rockies.

Equipment and Materials

... construction paper
... modeling clay
... knife

Extending the Concept

How do the Earth's pressures balance out? Several children might be encouraged to set up apparatus to illustrate folding and faulting resulting from pressure of sediment. Place several layers of construction paper, which represent rock layers, across the two stages of an equal-arm balance. On one stage place a pan of water. Exactly balance this with a pan of mounded sand. What can you do to represent erosion of the mountain? (Transfer some soil to the pan of water.) What will happen? (The mountain block will rise; the ocean block will fall.)

Equipment and Materials

... construction paper
... equal-arm balance
... pans (2)
... sand

What do you see in the layers of construction paper? (A fold.) Carefully cut through the layers between the stages. What do you see now? (A fault.)

The U.S. Geological Survey reports the West Coast is steadily rising at the rate of about one inch per year. How would you explain this to someone outside this class? As ocean beds are heaped heavier with sediment, the pressure causes upward movement by about an inch a year. The wearing down of the mountain by erosion is balanced by the building up of sediment.

What is the highest mountain in the world? After children make their guesses, give them a clue: Did you start measuring from the foot of the mountain? Did you start measuring under the ocean for any mountains? Mauna Loa, the great shield volcano in Hawaii, rises higher from its base (nearly 32,000 feet) than Mount Everest (29,028 feet). Hawaii, the Azores, the Aleutians, and various other Alaskan offshore islands are good places to look for island volcanoes. Back issues of *Life* and *National Geographic* have pictures and a story about Surtsey, a recent island volcano which appeared off the coast of Iceland in late 1963. Can you relate this event to the geysers and hot springs of Iceland?

Reviewing the Concept

(*Text pages 34–35*)

Before You Go On. A. 1. a 2. a 3. a 4. b

Section 6: TREASURE BENEATH YOUR FEET

Text pages 35–44)

SUBCONCEPT

he composition of the Earth's rocks s determined by the manner in which they were formed.

Processes emphasized

Field study
Investigation
Observation
Hypothesizing
Theorizing
Categorizing

Children, by examining kinds of rocks and studying their origins, relate the mineral composition of the Earth's rocks to conditions of erosion, pressure, and heat.

Introducing the Concept

For a change of pace, introduce the concept with a story. There is an old folk tale about treasure beneath an orchard. On their deathbed in midsummer an old couple who owned an orchard promised their sons rich treasure if they would dig for it. All through the rest of the summer, fall, and winter, the sons dug and raked but found nothing valuable. The next spring, showers of blossoms appeared on the trees. The digging and stirring up of the soil in the old orchard resulted in such a harvest that the sons reaped treasure indeed from their labors. What is this treasure beneath our feet?

Encourage children to think and to plan an exhibit of some of the Earth's substances. How many objects in this room are made from substances from the Earth? How many other objects can you see from the window? (A ten-minute study trip inside the classroom and outside the building could reveal slateboards, plaster walls, tile drinking fountains, outside brick- or stone-work, granite curbing, cement sidewalks, asphalt paving, iron fences, copper downspouts, etc.)

How are all these useful things related to the Earth? What other substances in the Earth are useful to us and other living things? How can we tell one kind of rock from another?

One activity of the scientist is to report to others. The sharing of knowledge is one attribute of the scientist's. Children discover that rocks may be grouped by their origin.

Equipment and Materials

. . . samples of igneous, sedimentary, and metamorphic rocks
. . . magnifying glass
(See text page 38; also the Teacher's Manual for *Classroom Laboratory* 5.)

Developing the Concept

Why do rocks look different? This is an excellent time to give children who have rock collections an opportunity to bring samples to class. Or, if you do not have available samples of rock similar to those pictured and identified in the children's textbook, a visit to a stone mason or a builders' supplier may reward you with various samples for display. Encourage the children, after they have read through "A Problem in Cooling," to try to separate from the samples all the rocks that have small crystals in them. Specific identification is unimportant at this time. Encourage use of the magnifying glass to detect the hard, glassy angles. From their textbook, children infer that they have separated igneous rocks from other types of rocks. You may wish to return to their selections later for modification of choice. If children have difficulty with the term *igneous,* draw their attention to *ignition* and *ignite.* All have to do with heat and burning. All igneous rocks were formed from rock melted by great heat.

Several children may now set up the investigation on text page 38. While awaiting results, proceed to the group identification of sedimentary and metamorphic rock. Why could a sedimentary rock, such as shale, not be mistaken for an igneous rock? It has layers (recall how sediment is laid down) which would not show if melted rock had cooled. It is relatively soft when compared with igneous granite, and children cannot see the hard, glassy, crystalline angles of reflection.

Rock identification is complicated because there are many gradations between sedimentary, igneous, and metamorphic rock. If children can group the broad generalizations, that is about all that should be expected. Interested children can, of course, be referred to the section at the end of their textbook for further work. On the basis of their textbook, children can help you develop a chalkboard chart such as the following.

ROCKS ARE CHANGED

Sediments	Sedimentary Rock	Metamorphic Rock
pebbles	puddingstone *	quartzite puddingstone
sand	sandstone	quartzite
clay mud	shale	slate
lime	limestone	marble
plant remains	peat (soft coal)	anthracite (hard coal)

* Another name for puddingstone is conglomerate, a mixture of pebbles and fine sediments.

Can igneous rock be changed? The perceptive child will relate weathering and erosion of igneous rock to the formation of sediments. He will also infer that granite, an igneous rock, may change after cooling and further heating, citing page 39 in his text. A rock sample labeled *gneiss,* from a child's collection, may have resulted from this heating action.

The look of minerals. Let the children work in as many groups as there are available magnifying glasses. Provide each group with a paper napkin and a teaspoonful of sand in a shallow container, such as a paper nut cup. You are now going to look at a combination of a gas (oxygen) and a metal (silicon). Each group spreads some of the sand on a paper napkin. What do you see? (Not a gas or a metal, but sand crystals.) Look at some finer or coarser grains. Do you still see crystals? What do they look like? If the sand comes from granite, you may see dark, shiny flakes (mica), flat-faced pink crystals (feldspar), and jagged, glassy fragments (quartz). The colors come from other substances mixed with the combination of the gas and the metal. Pulverize some sandstone and look for crystals. Study the surface of a bit of sandpaper. Can you see how the crystals in a rock can help you decide the kind of rock you have? What characteristics would you look for? (Size, shape, color of crystals.) Children may hypothesize that each mineral has its own kind of crystal and that conditions must be right for crystal formation; e.g., the substance must be in solution and there must be space for crystallization to take place.

Rocks may be identified by thei mineral composition.

Equipment and Materials

. . . magnifying glasses
. . . sand
. . . sandstone
. . . sandpaper
. . . paper nut cups
. . . paper napkins

Extending the Concept

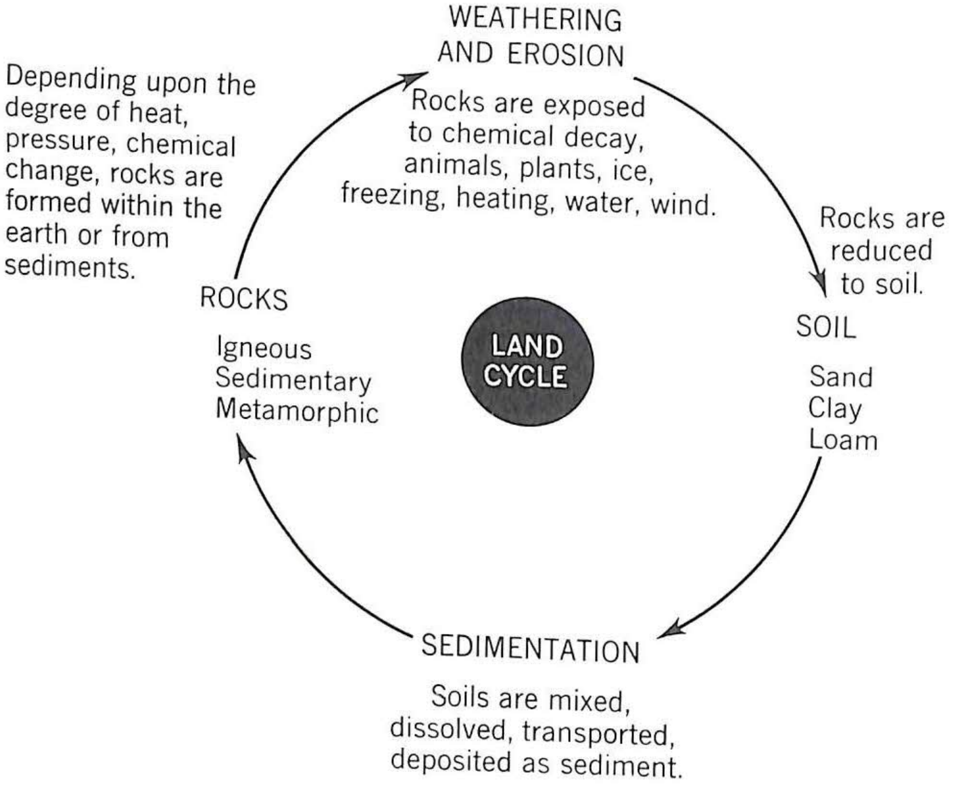
Equipment and Materials

- . . . sugar
- . . . salt
- . . . alum
- . . . Borax
- . . . Epsom salt

(See also the Teacher's Manual for *Classroom Laboratory 5.*)

What are some different crystals? Are all crystals alike in shape? The preceding activity can be extended by making available the substances listed in the margin, or others of crystalline nature. If classroom time is not available, interested children may work on their own. The substances should not be revealed until each group has completed an enlarged drawing of one of the substances. Use of a microscope (low power) would be desirable. Some members of the group may wish to make crystals following the procedures in the investigation (text page 38) or in *Crystals and Crystal Growing* by Allen Holden and Phylis Singer, Doubleday, 1960, a book available in many libraries.

The cycle of rocks into soil into rock. To tie together relationships between sediments and rock formation, children may reproduce the following as a large chart and explain it to the rest of the class.


WEATHERING AND EROSION
Rocks are exposed to chemical decay, animals, plants, ice, freezing, heating, water, wind.
Rocks are reduced to soil.
SOIL
Sand
Clay
Loam
SEDIMENTATION
Soils are mixed, dissolved, transported, deposited as sediment.
ROCKS
Igneous
Sedimentary
Metamorphic
Depending upon the degree of heat, pressure, chemical change, rocks are formed within the earth or from sediments.
LAND CYCLE

Reviewing the Concept

(*Text pages 43–44*)

Before You Go On. A. 1. a 2. b 3. b 4. a 5. b

Using What You Know. 1. *Igneous*—granite; *sedimentary*—limestone, puddingstone, shale, chalk; *metamorphic*—slate, marble. 2. The igneous rock will show no lines or other indication of where minerals have crystallized to replace tree parts.

Section 7: THE MAIN CONCEPT: THE CHANGING EARTH

(*Text pages 44–49*)

CONCEPTUAL SCHEME

The universe is in constant change.

UNIT CONCEPT

Bodies in space, as well as their matter and energy, are in constant change.

Processes emphasized

- Categorizing
- Concept forming
- Hypothesizing
- Theorizing
- Predicting

Children arrive at the understanding that the Earth is in continual change. As evidence, they can cite the continuous cycle of erosion and mountain building and slow but continual changes in the Earth's rocks and minerals.

CONCEPT SUMMARY

The young Earth. Has the Earth always been changing? What was it like in the beginning? In this section, the concepts of how the Earth is changing today are extended into the Earth's distant past when it was first formed. To encourage careful reading of the section, raise the following questions to stimulate children to test their hypotheses and their theories.

How do scientists think the Earth formed? Were there always oceans? Were they always salty? Where did the Earth's rock layers come from? Was there always life on the Earth? What do you think the Rocky Mountains will be like a million years from now? How can we predict what the Earth will be like millions of years from now?

On the basis of their study of the unit, children should be able to give good answers to these questions by considering earthquakes and volcanic action, weathering and erosion, changes in the Earth's rocks, and even radioactivity within the Earth. The purpose of the final section in this unit is to enable children to see how well they can use concepts to explain the past and predict the future.

How do we know when plants appeared on the Earth?

Forces that changed the young Earth. Why were plants not one of the agents of erosion in Earth's early history? (Environment was too hot; there was no soil.) How do we know? (Fossils are not found in the lowest layers of sedimentary rock.) As an example, the deepest exposed layers of rock in the Grand Canyon have no fossils, but sedimentary layers just above them show fossil algae—primitive plants. Grand Canyon is over a mile deep. What does the depth of this fossil layer tell you about the location of the Grand Canyon millions of years ago? (It must have been at the bottom of the ocean.)

How can we tell the age of mountains?

Young mountains or old. With your hands, suggest the shape of a young mountain. An old mountain. Can you find pictures in magazines or books (do not cut out without permission) to illustrate the age of mountains? In your social studies books, are there pictures of the Appalachians, Rockies, or Sierras? Of other mountains? Which ones are older? Which younger? A display would add interest to the class bulletin board.

Why are the seas salty?

What are rocks made up of? The resolution of this question should lead to an understanding that many kinds of minerals exist in the rocks. Do the minerals stay in the rocks? (No.) What happens to them? (Dissolve in rain water.) Can you explain why scientists think the early seas were like fresh-water lakes? How did the oceans become salty? Why is Great Salt Lake more salty than the oceans? Do you think the oceans a million years from now will be more, or less, salty? What is your reason?

How do radioactive substances release energy?

Equipment and Materials

- . . . watch or clock with luminous dial
- . . . magnifying glass

Radioactivity releases energy. You have learned that radioactive rocks release energy when the nuclei of the atoms break up. How can we show a radioactive substance releasing energy? Take a clock or watch with a luminous dial into a dark room. Stay in the room until your eyes become used to the dark—usually seven to ten minutes—and then look at it with a magnifying glass. You will see tiny sparks jumping from a radioactive substance in the paint on the dial. Any explosive release of energy is accompanied by heat, but of course there is so little in the radioactivity of the dial that it is not noticeable. How is the Earth like a heat engine? How does radioactivity of substances in the Earth cause changes? (Heat and pressure may cause slow upheaval or rapid release of pent-up energy through volcanoes, both accompanied by faulting, folding, or earthquakes.)

(*Text pages 46–49*)

FIXING THE MAIN CONCEPTS

Sample answers are suggested for the above-titled section in the children's text. Children may give other acceptable answers they can defend on evidence gathered from their studies and investigations. They should be encouraged to phrase their own statements of ideas and concepts and support them with as much information as they can.

A. **1.** On dying, the fish was covered with sediment that became rock and was uplifted by pressure on and in the Earth. **2.** Pressure; ice, tree roots, or an earthquake may have exposed the rock. **3.** Quickly; rapidly moving water would have carried the smaller particles farther. **4.** Granite; its particles were probably formed by cooling of magma. Limestone is sedimentary rock; granite is igneous rock. **5.** Rivers deposit sediments in lower areas. **6.** The river carries sediment that builds up as the flow of water slows near the river's mouth.

B. Student sentences; the glossary, as well as the sections in the child's text, will aid in verifying whether the sentence context conveys the concept.

C. **1.** b **2.** a **3.** d **4.** c **5.** b

About This Book

In your lifetime men are going to explore strange planets.

You are, in your own way, an explorer of a strange planet—a planet you came some time ago to live on. You didn't arrive on this planet in a spaceship. You don't need a space suit to go about on its surface. But don't think then that this planet—spinning 18 miles through space every second—isn't strange or worth exploring. It is a strange planet indeed, full of amazing things.

This book will help you to explore planet Earth.

PLEISTOCENE PERIOD
TWENTY-FIVE THOUSAND YEARS AGO

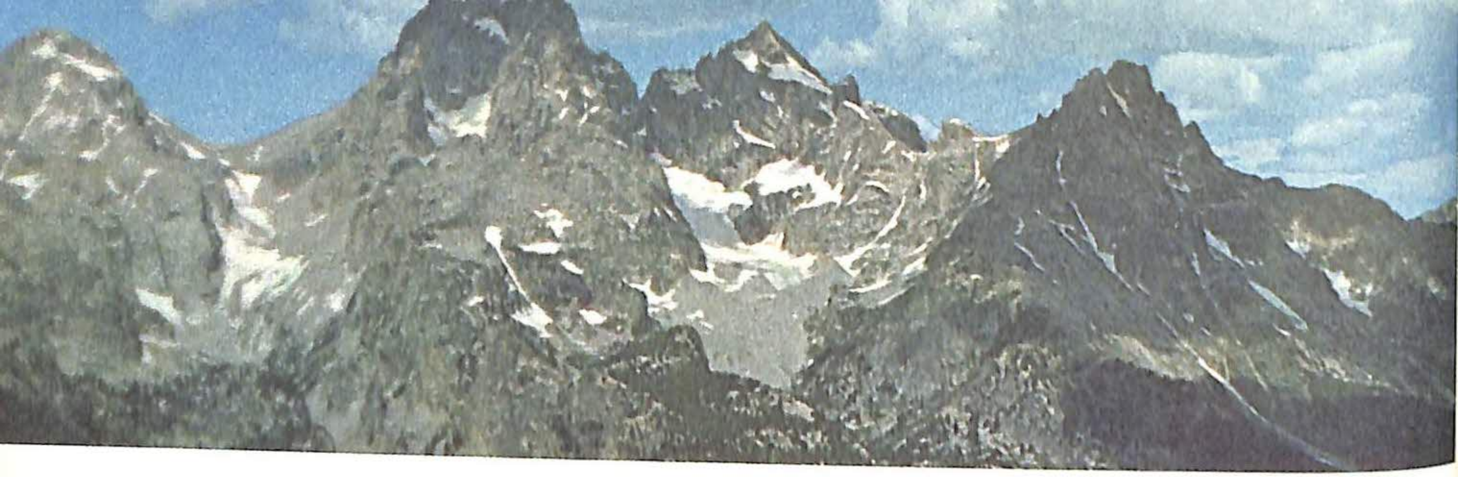
UNIT ONE

THE EARTH- INSIDE AND OUT

One Saturday Jimmy Ruhle, 13 years old, watched some workmen digging and saw some bones uncovered. Young as he was, Jimmy had studied fossils—and he knew at once that these were fossil bones. He gathered up the pieces and hurried off with them to Doctor Horace G. Richards, a scientist whom he knew.

Doctor Richards studied the bones carefully. They were part of the skeleton of a great ground sloth (slōth), he said, that had lived about 100,000 years ago. Jimmy had found what scientists had been searching for over many years! (This discovery helped Jimmy to decide that he would study to become a scientist.)

Jimmy's find was a surprise, certainly. Isn't it surprising too, when you think of it, that Dr. Richards could recognize the bones? How does a scientist know what animals roamed the Earth so long ago? Indeed, how does he know how long ago they lived? Strangely enough, the answers begin with the breaking down of a mountain.



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1. Breaking Down a Mountain

Thomas Jackson, better known as "Stonewall" Jackson, was a Confederate general and a most determined man. He stood firm in battle—like a stone wall, people said. People do think of stone and rock as standing firm and forever.

Yet we know it isn't so. In time even the hardest rock crumbles. In fact we can find material all around us that was once rock. This handful of sand was once hard rock. See the picture marked with a square. ■

How can rock be broken down?

■

Watching for a Million Years

If you could watch a mountain for a million years or so, you would see how rocks—and mountains—are broken down.

At first, when a mountain is young, its edges are rough and jagged. Its rocky peaks have the shape of upside down **V**'s. ●

But by day the heat of the sun acts on the bare rock of the young mountain. The heat causes the rock to expand. By night the rock cools, and contracts. Day and night the rock expands and contracts, expands and contracts, again and again. Cracks appear in the rock, and deepen.

Water seeps into the cracks. Cold weather turns the water to ice. When water turns to ice, it grows in size. It expands. This expanding produces a force—a force that can split rock!

See for yourself how freezing water can expand and force things apart. Try the investigation on the opposite page.

AN INVESTIGATION into the Force of Ice

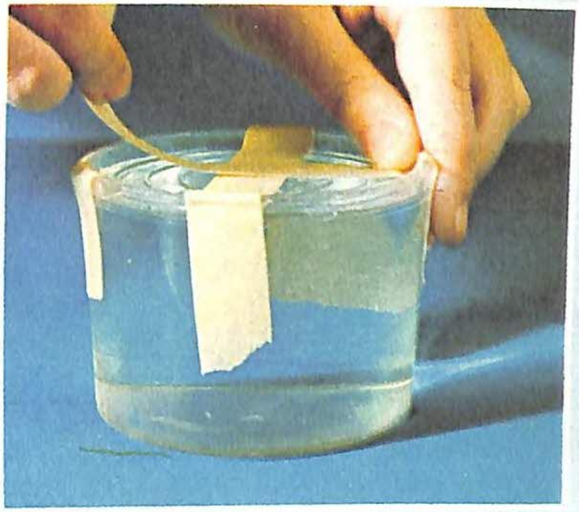
Needed: a stiff plastic refrigerator container with lid, a roll of cellophane or masking tape, a refrigerator, water

With water, fill the plastic container to overflowing. Then put the lid on carefully, so that there is no air in the container—only water. Tape the lid on tightly. ■ Put the container in the freezer of a refrigerator or let it cool outdoors if the temperature is below freezing. Leave it there long enough for the water to turn to solid ice.

Here is what happened to a plastic container in one trial. ●

There can be enough force in freezing water to split rock.

Additional Investigation: Fill the plastic container with water again, just to the top. Do not put the lid on. Predict what will happen to the water level as the water turns to ice. Test your prediction.



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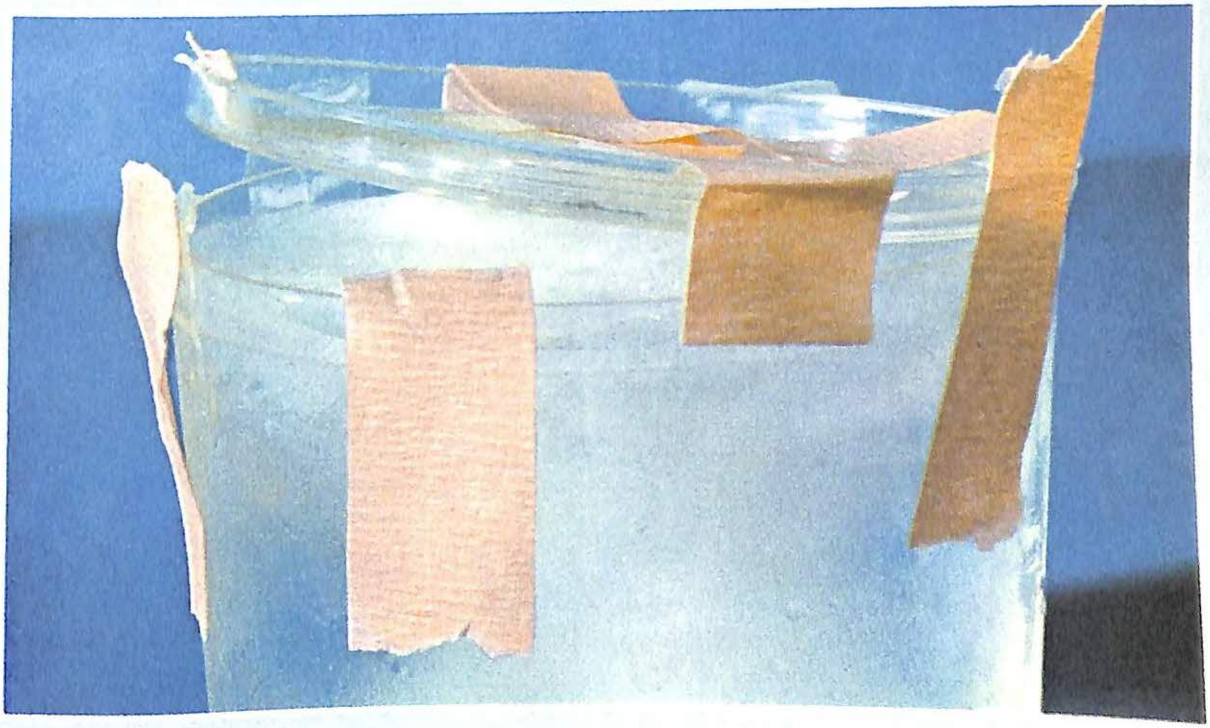

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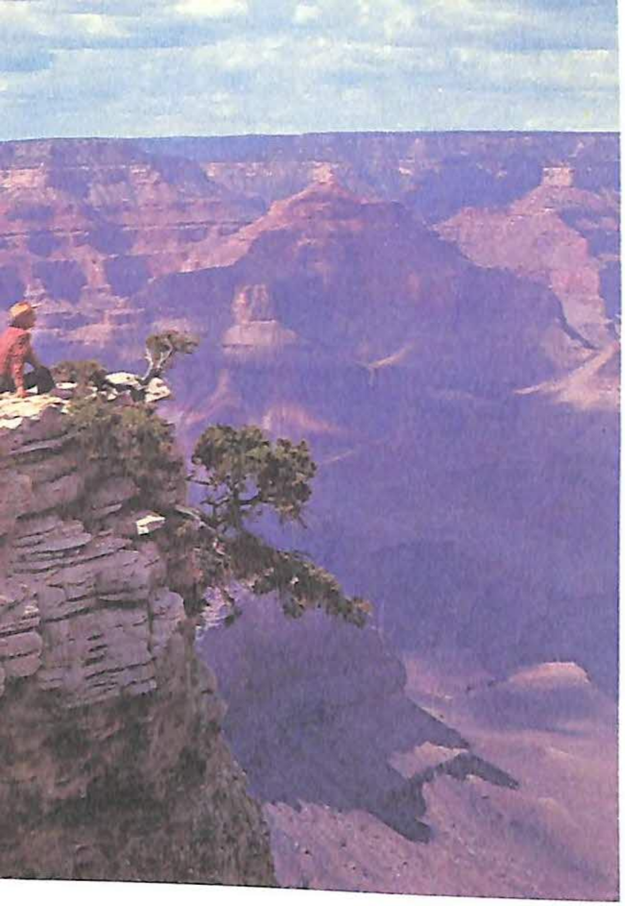

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A Saw of Water

As water freezes in cracks, rock is split apart. The heat and cold and water that weather brings can crack a rock, split it open, and break it down. ■ In time a rock may be worn down into a handful of sand.

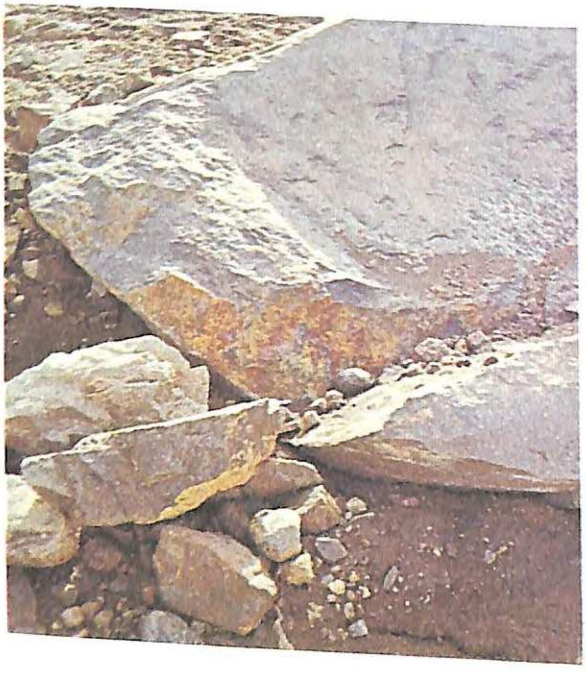
The breaking down of rock by weather is called **weathering.** Watching a mountain for a million years or so, you would see the sharp edges and Λ-shaped peaks of the young mountain being worn down by weathering. You would see the edges and peaks becoming rounded and smooth, as the forces of weathering worked on them.

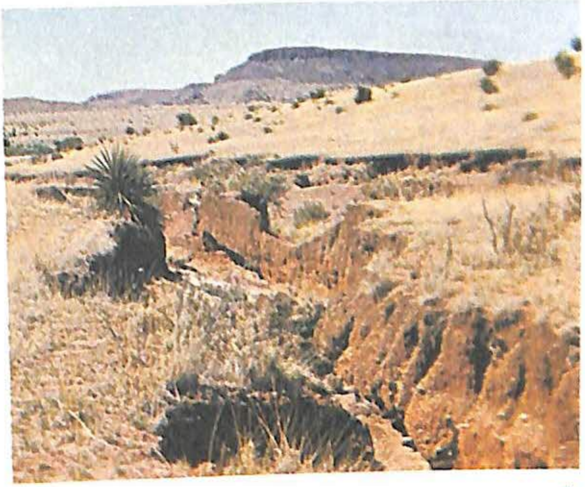
However, heat and cold are not the only forces that break down and wear away mountains. A visit to the Grand Canyon will show you another force at work.

The sight of the Grand Canyon takes one's breath away. ● The beauty of the colored bands in the light of the setting sun is hard to believe. Each band is a layer of rock.

Millions of years ago there was no canyon here. There was only the river, flowing across the plain. As the river flowed, however, it carried along rocks and pebbles. Rolling and bumping and scraping along the river bottom, the rocks and pebbles dug the channel deeper. Thus the river wore away the rock over which it was flowing. We call this wearing away of the Earth's surface **erosion** (i·rō′zhən).

■





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By erosion, the river cut its way down through the rock layers like a giant saw.

There are other forces of erosion at work besides rivers. Look at the strange forms of these rocks. ▲ When the wind blows here, it hurls sharp grains of sand against the rocks. Over the years the rushing wind and biting sand have eroded the rock, much as sandpaper wears down wood. Erosion is the sculptor of these giant figures.

So erosion shapes the land—and breaks down the land, too. This gully was made by running water. ◆ At first no one noticed the crack in the ground made by running rainwater. But every

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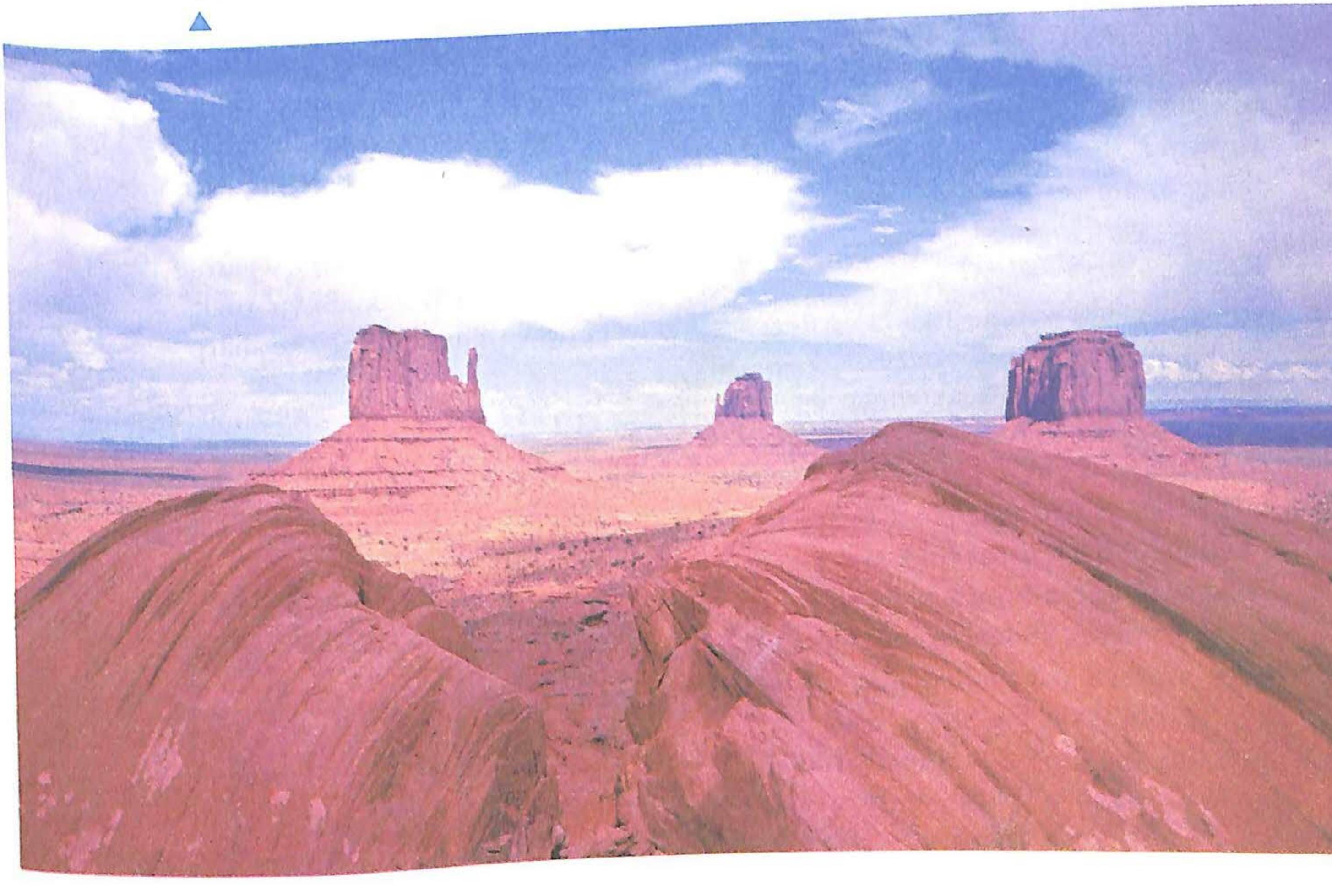

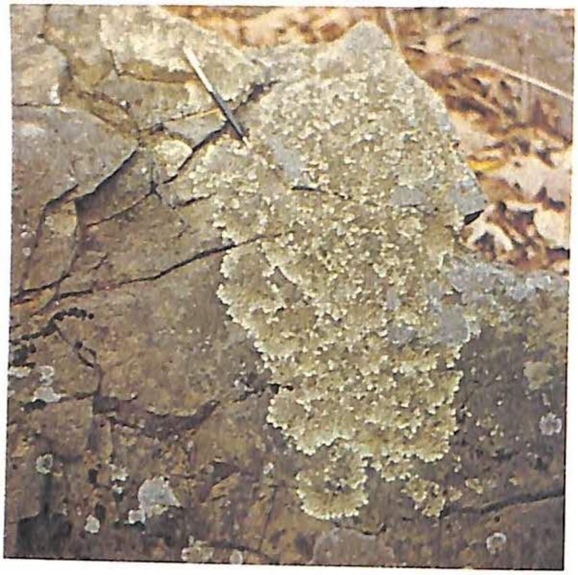

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rain carried away more soil, and made more room for erosion. The result: precious soil was lost.

Water and wind erode rock, and carry it away. Heat and cold and freezing water break rock down. However, they have help from living things—from plants.

Plants at Work

If you could watch a mountain over a million years or so, you would see plants helping to break down rock, especially the plants called **lichens** (lī′kəns).

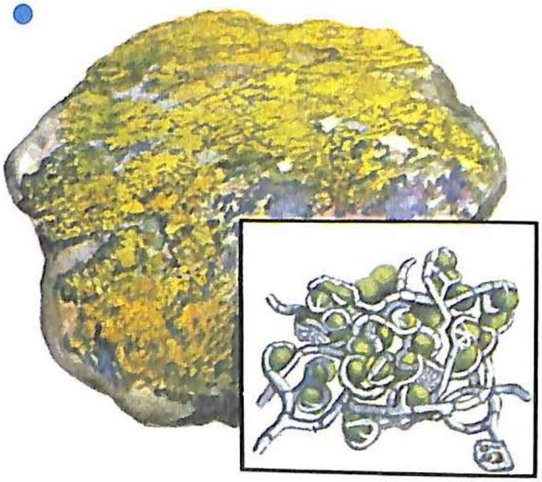
A lichen is a strange plant. ■ It can stand great heat, great cold, and great dryness. It is really *two* plants, one a colorless plant called a fungus, the other a green flat-bodied plant. The two plants live together, with the threads of the fungus wrapped around the green plant. ● The threads of the fungus help to hold water, and the green plant makes food. Perhaps the two plants depend on each other.

Looking at the lichens on the mountain, you would see them gripping the rock. You would see specks of wind-blown soil caught in the lichens and fastened to the rock. Most remarkable of all, you would find that lichens make a chemical substance that helps break down rock and form soil.

Some of this soil slides into a crack in the rock. Then seeds fall into the crack. Strange as it may seem, seeds in a crack can have much the same effect as ice, for as seeds soak up water they expand. Have you ever noticed a plant forcing its way through a crack in a sidewalk? Such growing plants are powerful. They can help to break rock apart, and to break down a mountain.

During several million years, weathering and erosion break down rock, and wear down a mountain. The sharp

●



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peaks of the young mountain become rounded to the shape of a **U** upside down. As **Λ** changes to **∩**, the young mountains become old mountains.▲

Where does all the weathered and eroded rock go? Some of it is spread on the land, and becomes part of the soil. Some of the weathered and eroded rock is carried by rains and rivers into the oceans. We will look at the bottom of the ocean and see what happens there.

All around you the forces of erosion and weathering are carrying away soil, wearing away rock and breaking down stone. Do you have to watch a mountain to see these forces at work? No, indeed. Wherever you live, in the country or in the city, you can see these forces at work—if you look.

You have just read and studied a section of this book. What have you learned? We can help you to find out for yourself. At the end of each section you will find a part called "Before You Go On." It will help you pin down the main ideas or concepts of the section. Try these questions, problems, and things to do.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. When rocks are heated, they
a. expand b. contract

2. When rocks are cooled, they
a. expand b. contract

3. When rocks are broken down by heat and cold we call the process

a. weathering　　b. erosion

4. When bits of rock or soil are worn away by wind or water, we call the process

a. weathering　　b. erosion

B. Write a paragraph or two on this topic: "How a Mountain Is Worn Down."

USING WHAT YOU KNOW

1. A hillside may be plowed along or across the slope. Which way is best for saving water? Which is best for saving soil? What are the reasons for your answers?

2. A farmer has a fast-running stream on his land. He is advised to build small dams (called check dams) across the stream. Of what use will check dams be?

3. How would you recognize an old mountain? How does a young mountain differ from an old mountain?

ON YOUR OWN

Wherever you live, you will find weathering and erosion at work. Look for:

a. Sidewalks cracking or lifting. Was ice the cause?
b. Walks or rocks with plants growing in the cracks. What may happen?
c. Soil carried into the street. What happens to the soil?
d. Streams brown with soil. Where does this soil come from?
e. Roads with bumps, holes, and cracks, after a winter. What tears down the road?
f. A gully down a hillside. Is it getting deeper?

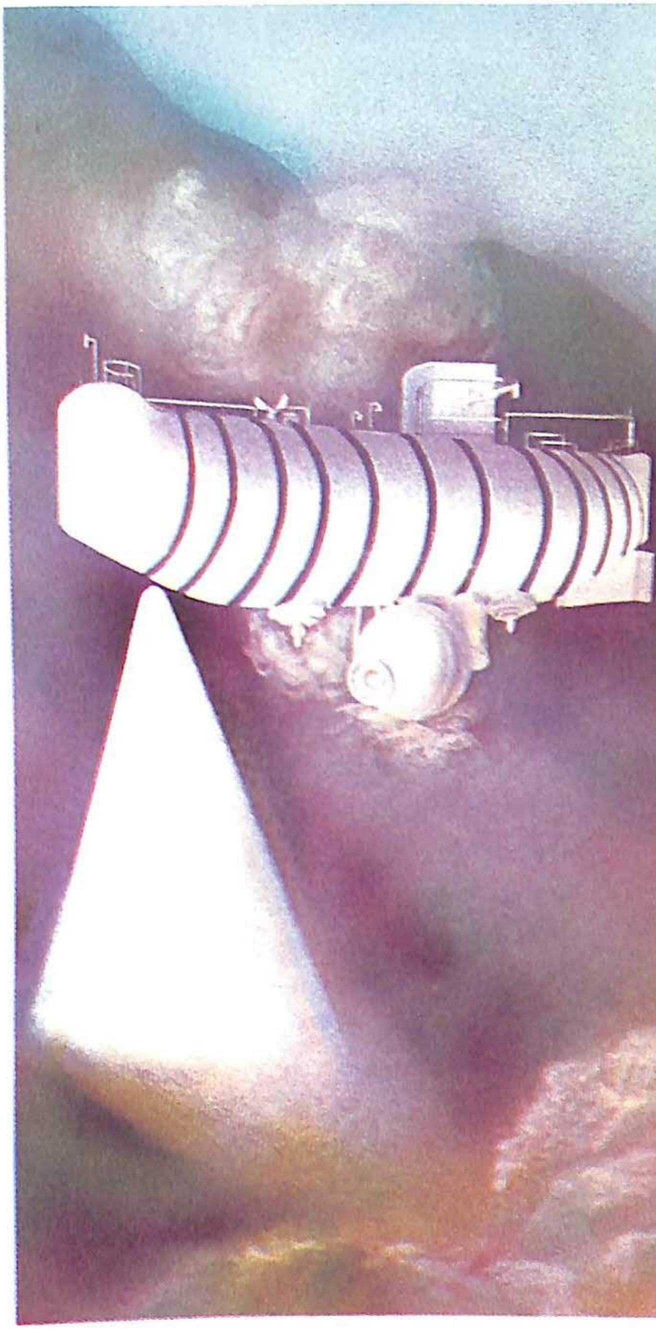
2. Building Up the Land

We have seen how the land is broken down. Now let us see how it is built up. To see this we must go, of all places, to the bottom of the sea. Of course we must find a way to get down.

To go to the sea bottom is the job of the special kind of ship shown here.■ It is a **bathyscaph** (bath′ə-skaf).

The bathyscaph has taken men to the bottom of the deepest hole in the deepest ocean—and has brought them back alive. Jacques Piccard, son of the bathyscaph's designer, and U.S. Navy Lieutenant Don Walsh went down almost 7 miles. Mt. Everest is 6 miles above sea level, so the bathyscaph went about a mile deeper below the surface of the sea than Mount Everest is high above it.

The bathyscaph floats in water much as a balloon floats in air. A balloon floats in air because it is filled with a gas that is lighter than air. The bathyscaph *float* is filled with gasoline. (The float is painted with stripes in the picture.) Gasoline is lighter than water. Hence the bathyscaph floats in water.



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To sink, the bathyscaph must take on more weight. The pilot lets sea water into the hatchway that goes through the float to the *capsule*. Both the pilot and the observer sit in the chamber, below the float. To return to the surface, the pilot lets go iron weights held within the bathyscaph by electromagnets. When the weights drop away, the bathyscaph rises.

■

What is there to see from the window of a bathyscaph miles down in the ocean? Strange fish swim out of the dark into the bathyscaph searchlights, and swim away into darkness again. ■ They live under the pressure of tons of water. Somehow they find food in the dark. One fish has a huge mouth to capture its food. Another has a kind of chemical lantern at the end of a long whip growing from its head. Can it see in the dark with this lantern? We do not know. It is a strange creature, in a strange place.

●

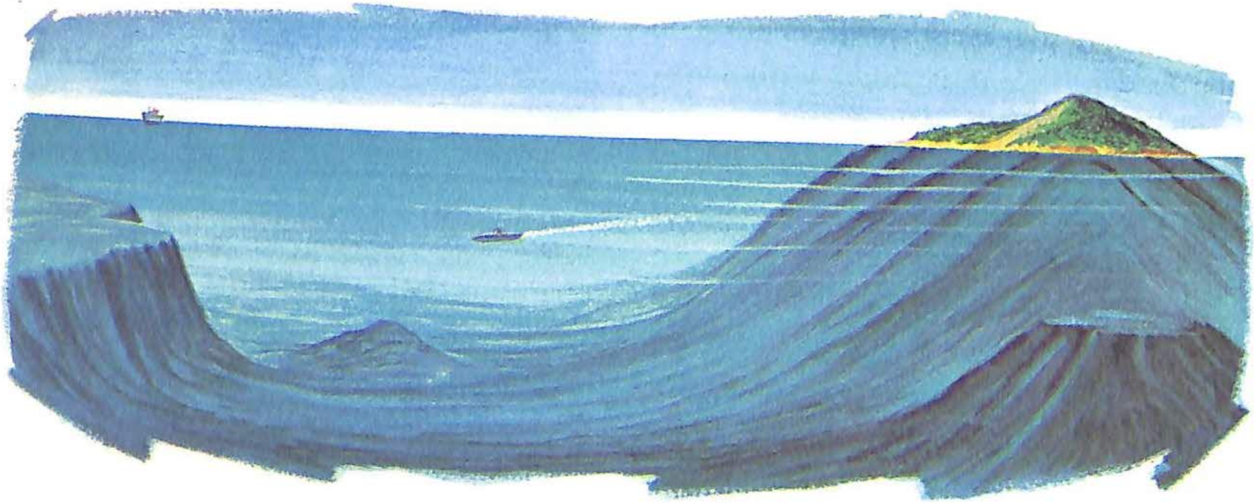
Then there is the ocean bottom. It is not just a smooth, flat floor. Like the land, the ocean bottom has mountains, valleys, and plains. ● Some of the mountains rise so high that their peaks are above water. We see these peaks as islands. Many islands are actually the peaks of mountains under the sea.

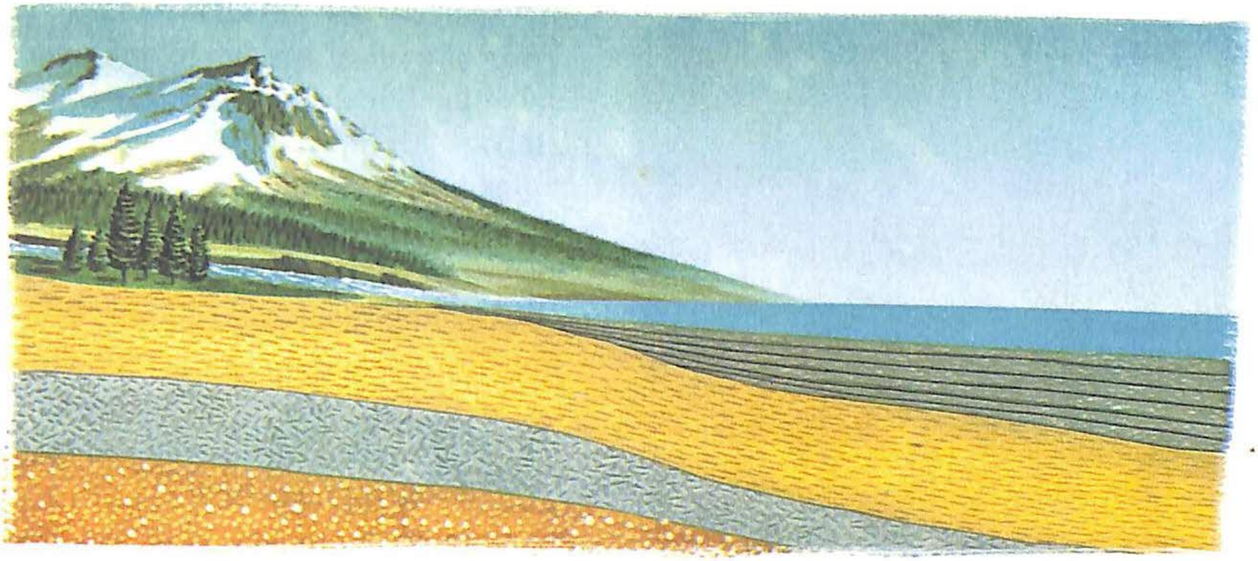
There is another strange thing we can observe in the sea, especially near the shore. It is a kind of rain, a rain of material falling through the water to the sea bottom.

Rain Under the Sea

Tiny rocks, pebbles, grains of sand, specks of soil, and other material, are raining to the bottom of the sea. Sometimes the rain of specks and particles and bits is heavy, sometimes it is light. But it goes on, year after year.

Where does this rain come from? Think of the rivers flowing from the land down to the sea. Every river is





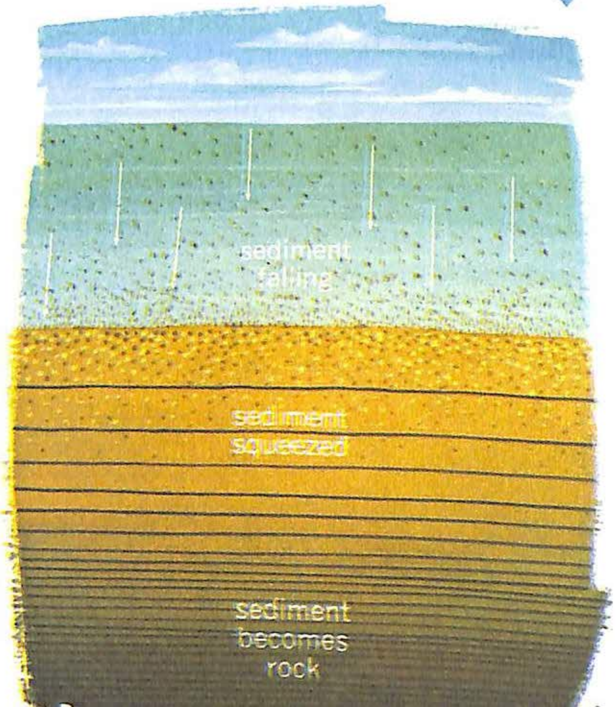
▲

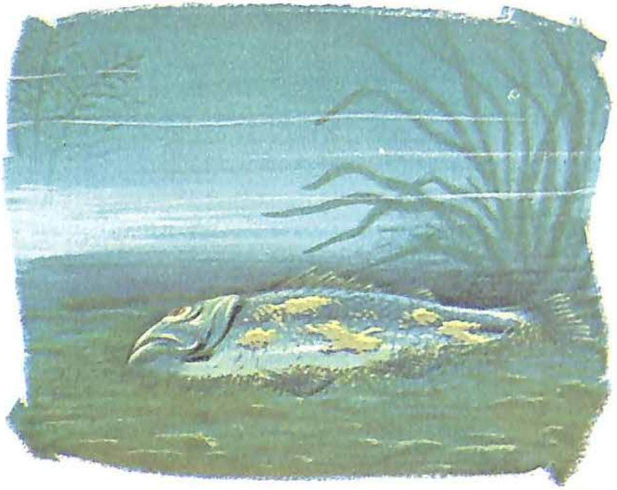
doing its work of erosion, and is carrying along particles of rock, soil, and other substances that it has picked up on its course. We call all this material that is carried along **sediment** (sed′-ə·mənt). The river dumps its load of sediment into the sea. All along the coast, sediment is poured into the sea by rivers. ▲ Year after year that sediment rains down on the ocean floor.

Sometimes the rivers coming down to the sea are full to overflowing. As they rush along they bring a heavy load of coarse sediment, with many large pieces and even good-sized rocks. At other times the rivers move slowly, and do not have so much force. Then the sediment is made up of small specks and tiny particles. Because of these changes in rivers, something happens at the bottom of the sea. Layers of sediment are laid down on the sea bottom. A layer of coarse sediment is covered by a layer of fine sediment. Then that fine layer is covered by a coarse layer—and so on.

Year after year, hundreds after hundreds of years, the layers of sediment pile up. The top layers press down on the bottom ones. The bottom layers are squeezed harder and harder by the growing weight of layers above them. *The bottom layers of sediment turn into layers of rock.* ◆

◆





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So in time, layers of sediment can become rock, **sedimentary rock.** Think how very important this forming of sedimentary rock is to us. First, the forming of sedimentary rock is *building up* the land. While a river is eroding and carrying off land in one place, in another place it is laying down sediment and building up land.

Second, sedimentary rock is important because it is in sedimentary rock that **fossils** are found. A fossil is the preserved remains or the print of a living thing of long ago. It is from fossils that we learn of the living things that were on the Earth before man.

You can easily make a model of layers of sediment piling up under water. See for yourself how this happens, as shown on the opposite page.

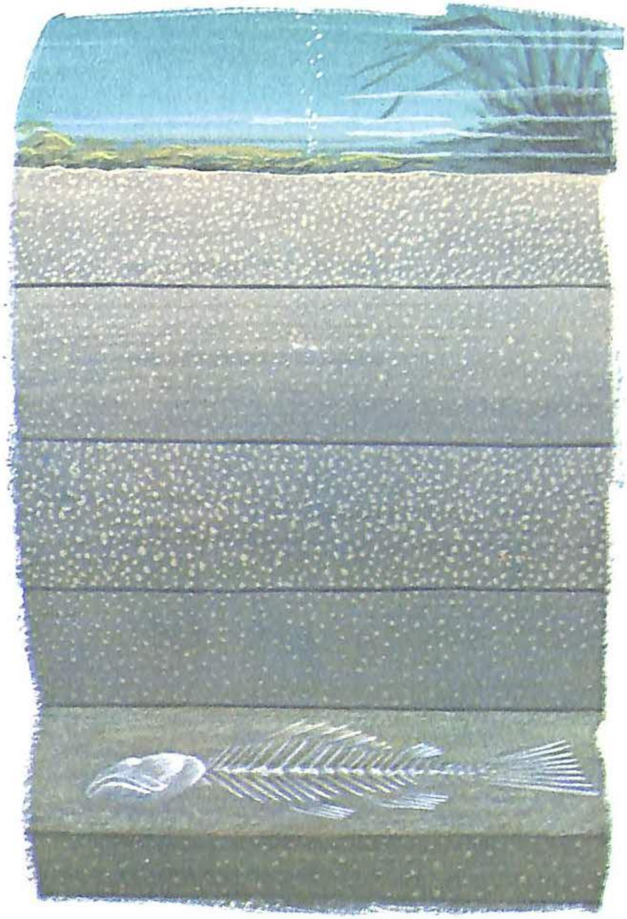
The Making of a Fossil

When a plant dies, it decays and disappears. It becomes part of the soil. When an animal dies, it too decays and disappears.

But sometimes a dead plant or a dead animal does not disappear completely.

Imagine that long, long ago, in an ancient sea or lake, a fish dies. It sinks slowly into the sediment at the bottom. Imagine it lying there. Now sediment rains on top of it. ■ Slowly, over thousands of years, layers of sediment build up over the remains of the fish. ● Slowly the layers of sediment turn to rock. Within the rock the remains of the fish are preserved. The remains may have become rock themselves. Or they may have left their

●



MAKING A MODEL: Layers of Sediment

Needed: about a pint of soil; about a pint of pebbles, gravel, and sand; a tall glass jar that will hold 2 quarts or more; water

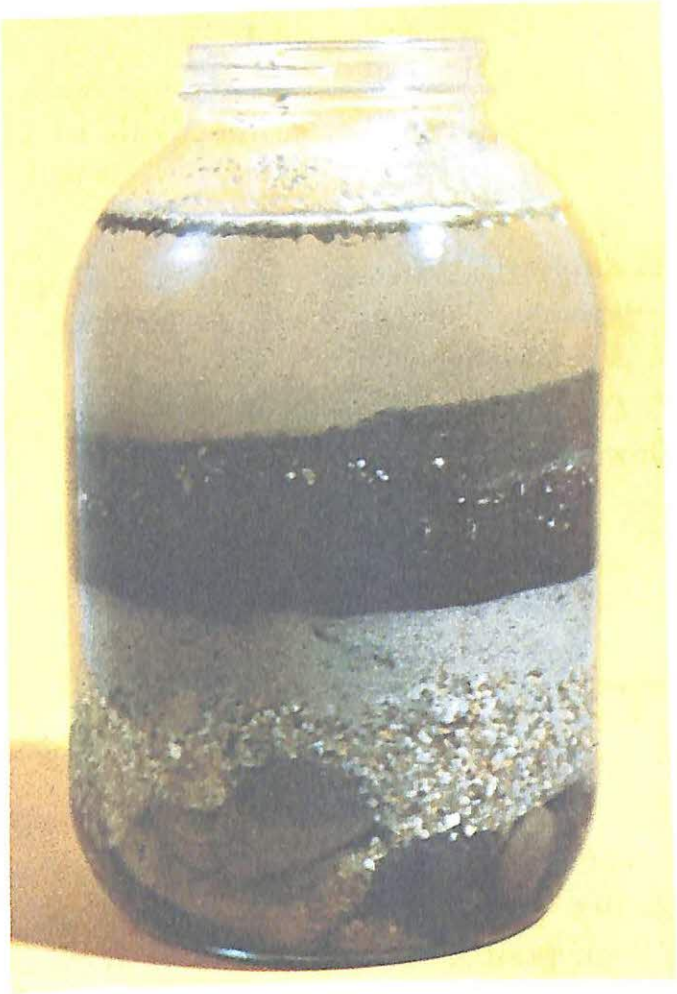
Put the soil, pebbles, gravel, and sand in the tall jar. Add about the same amount of water.

Shake up the mixture, or stir it up thoroughly. Then let it stand. Observe how the sediment settles to the bottom.

Here is a photograph of one trial. ■ What do you observe?

Sedimentary layers on the ocean bottom may be much like the layers in this model. Larger rocks and pebbles settle first. Then coarse sediment sinks to the bottom, and fine sediment comes last.

Additional Investigation: What sediment settles to the bottom first? Can you explain why and test your explanation?



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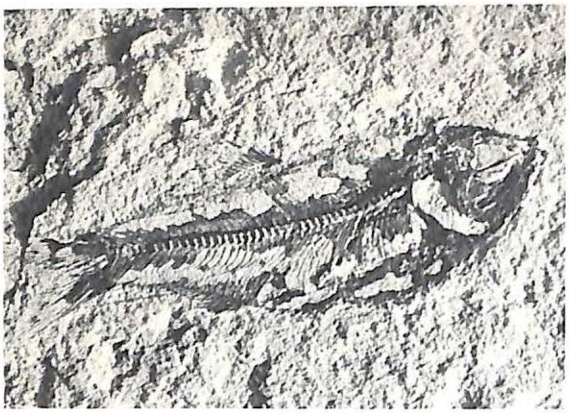


■

shape in the rock, as this ancient fish did. ■ The remains have become a fossil, the preserved remains or the print of a living thing of long ago.

In this way shells, plants, bones, even whole skeletons, have become fossils in sedimentary rocks. It takes a long time, of course. Indeed, it takes millions of years for this fossil to form.

Isn't there something strange here, however?

Fossils are formed beneath the sea. Yet fossils, you recall, are often found *on land.*

How do fossils come to be on dry land?

Try your hand at inventing a **theory** to explain this. A theory is a possible explanation of the facts discovered by investigation. You will find out how good your theory is as we go deeper into the Earth and you get a better idea of the structure of this planet. Then you will have more facts to think with.

First, however, let's make a model of our Earth from what we know about how it is built up.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Sediment carried by the rivers into the ocean is put down in

a. layers b. piles

2. The remains or print of an ancient animal or plant in sedimentary rock is a

a. skeleton b. fossil

3. In one place, erosion breaks down land. In another place, sedimentary rock

a. builds up land b. breaks down land

4. Old sedimentary rocks may have in them a record of the Earth's

a. present life b. past life

B. Now put to work some of the concepts of the section you have just read. Write a paragraph or two on "Why Sedimentary Rocks Are Important."

USING WHAT YOU KNOW

1. There are four layers of sedimentary rock. Layer A is on the bottom, layer B is on top of A, C is on top of B, and D is the topmost layer. Which layer is oldest? Which layer is youngest? Explain your answers.

2. Some sedimentary rock has large pieces in it. It is coarse sedimentary rock. Other sedimentary rock is very fine. What kind of river may have brought the coarse sediment? What kind of river may have brought the fine sediment?

ON YOUR OWN

1. You might want to try making a model of a fossil. Mix plaster of Paris with water in a shoe box until there is a layer of paste about an inch thick on the bottom of the box. This paste is a model of a sedimentary layer. While the paste of plaster is soft, place on it a clam shell covered with a very thin coat of Vaseline. Add a leaf or a chicken bone, also smeared lightly with Vaseline, so that the plaster won't stick to it. Cover them with another inch of plaster, and let it harden. In this model of sedimentary rock layers are the remains of plants or animals which were once alive. They are caught in plaster as fossils are in sedimentary rock.

How can you get at the "fossils" in the model?

2. Many people enjoy collecting rocks. You might enjoy this hobby too, and learn a good deal about the Earth, the planet on which you live. Start by examining "Probing the Earth's Crust" at the end of this book.

3. We Build an "Earth"

Our reason for watching a mountain was to see what happened to it. We saw that over a million years or so the mountain was broken down into sediment. Our reason for going into the sea was to find out what happened to that sediment. The sediment was built up into sedimentary rock.

We have found out something important. Our Earth is not a quiet planet. Its surface is always changing.

Perhaps you have had in mind a different picture of the Earth. Perhaps you have thought of it as an unchanging solid ball, revolving peacefully around the Sun. The Earth is not an unchanging ball at all, on the outside at least.

What about inside the Earth? Let's look beneath the surface. We can begin by making a model of the Earth.

A First Model of the Earth

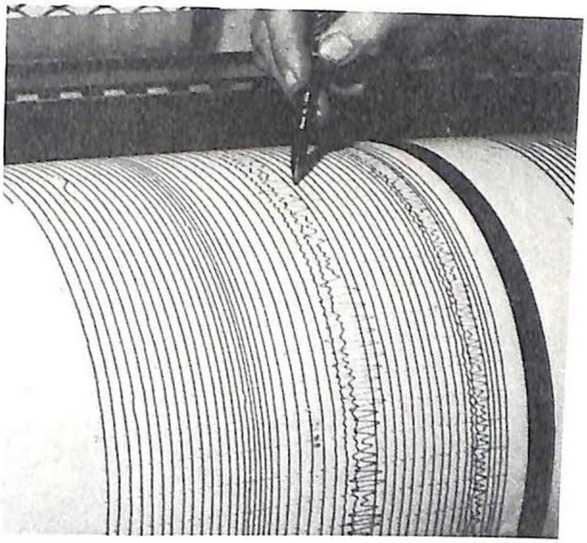
Have you ever built a **model**—a model boat, a model airplane, a model of a house? If you have, then you know that a model can teach you a lot about how things work. For this reason, scientists often are model makers. Models help a scientist to think, and to understand. They are especially useful when he is dealing with something too large to handle, like the Earth, or too small to see, like the atom. Ask a scientist to explain something, and he may reach for some models to show you. Ask a scientist what the inside of the Earth is like, and he might reach first for an orange.

An orange can be one model of the Earth. An orange is a ball; so is the Earth. An orange has a rather tough, thin, hard skin; so has the Earth. And the soft inside of the orange can stand for the inside of the Earth.

How can scientists know what the inside of the Earth is like, far beneath the layers of rock on the surface? Men have been able to go 7 miles down into the sea, as you know. However, they have not been able to get very far into the solid Earth. The deepest hole drilled has gone down only a few miles, only into the orange skin, that is. How is it possible then for scientists to get an idea of the inside of the Earth, thousands of miles below your feet?

Studying Earthquake Waves

There was a time when men could not send satellites into space. Yet men did search space—with the telescope. Men have invented instruments to explore where they cannot go themselves. To discover what the depths of the Earth are like, men use an instrument called the **seismograph** (sīz′ mə·graf). ■ A seismograph is an instrument for observing **earthquake waves.** When the waves caused by an earthquake reach a seismograph, its pen swings across the moving roll of paper. ● Studying seismograph records like this one, scientists can tell how strong an earthquake was. ● They can even tell where the earthquake took place by comparing records from different seismographs. The earthquake that made the recording shown happened in the Atlantic Ocean. The seismograph that made this recording was in Oklahoma.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There is more that scientists have learned from the seismograph. Scientists have learned how to tell differences between earthquake waves. They can tell whether earthquake waves have traveled through one part of the Earth or through some other part.

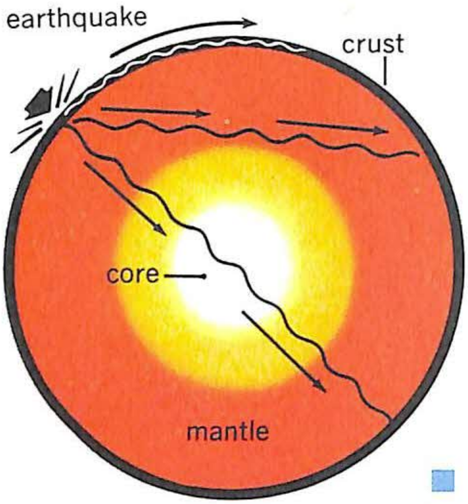
Waves in the Earth

On top of the Earth is a very thin layer of soil in which plants grow. Below this soil is a skin of hard rock called the **crust.** We usually think of the Earth's crust as firm and unmoving. "Firm as a rock," we say.

However, the rock layers of the crust can move. Sometimes a part of the crust shifts to a new position. Sometimes the shift is very slow, and takes hundreds of years. But sometimes the crust shifts suddenly. When that happens, there is an earthquake. The earthquake need not be one in which buildings fall and towns are buried. It may be so gentle that it can be detected only by instruments such as the seismograph.

Wherever there is an earthquake, however, earthquake waves are started. The waves travel out from that place through the Earth in all directions.

Can a wave travel through anything as solid as the Earth? You can easily see—or rather, hear—for yourself.



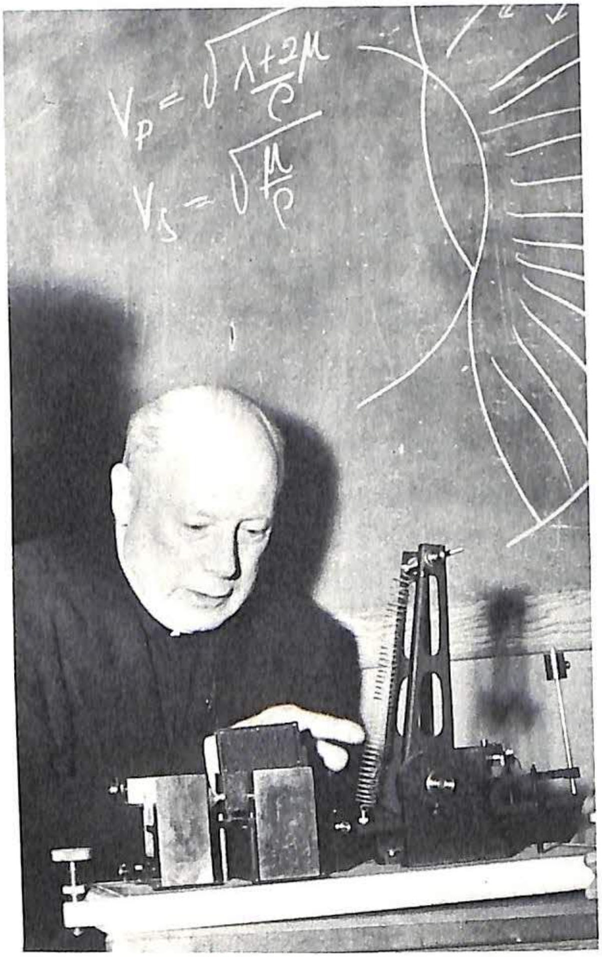
Put your ear to the top of a desk or table, at one end. Have someone tap the other end with a pencil. Listen. Then raise your ear and listen to the same sound as it reaches you through the air. What difference do you find between the sound traveling through the solid desk and traveling through air?

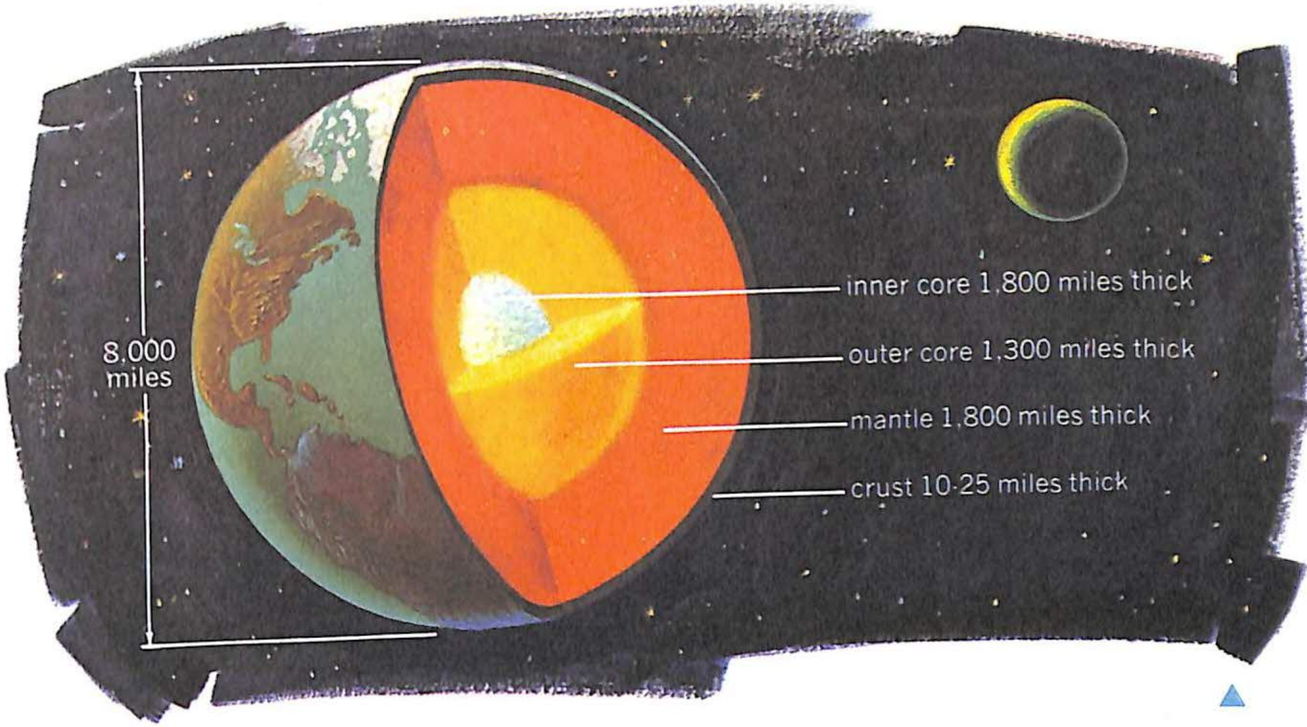
Put your ear to other parts of the desk and you will find that the sound of the tapping is traveling out from its starting point in all directions. Notice what happens to the sound as you come closer to the point where the tapping is taking place. Is the sound louder or softer?

The tapping pencil makes waves, waves that travel through the solid desk to your ear. Waves *can* travel through a solid. The sudden shifting of the Earth's crust in an earthquake makes waves that travel through the Earth. ■

Earthquake waves are not sound waves. As you go on in your study of science you will learn why. In some ways, however, earthquake waves and sound waves act alike. You detect sound waves with your ear. Scientists detect earthquake waves with the seismograph.

We have been talking of earthquakes as if they happened often. They do. Rev. J. Joseph Lynch of Fordham University has been studying earthquakes all his life. ● He reports that there is at least one earth-


$V_p = \sqrt{\frac{\lambda + 2\mu}{\rho}}$
$V_s = \sqrt{\frac{\mu}{\rho}}$



quake every day somewhere in the world. However, most of the records made on seismographs show only small shifts and movements of the Earth's crust.

By studying these earthquake waves, scientists are finding out what the inside of the Earth is like.

The Earth's skin, the crust, is made of hard and solid rock from 10 miles to 25 miles thick. Compared with the size of the Earth, however, the crust is very thin.

This diagram shows what scientists think the Earth is made of. ▲ Under the crust is a layer of rock called the **mantle.** In the mantle are many of the different substances of which the Earth is made. The mantle surrounds the **core,** which seems to be mainly melted iron and nickel. The mantle is probably white hot and melted near the core. The core is the densest part of the Earth.

The Earth is about 8,000 miles in diameter. How thin is the crust you walk on, compared to the size of the Earth! Geologists (je·ol′ə·jists), the scientists who study the Earth, hope to drill a hole through the thinnest part of the crust, which lies under the ocean. What will they find when the drill gets through the crust? You can follow the discoveries of the geologists in newspapers, magazines, and on television.

The orange is not a good enough model to show what scientists may find. Let us try another model, the one on the next page.

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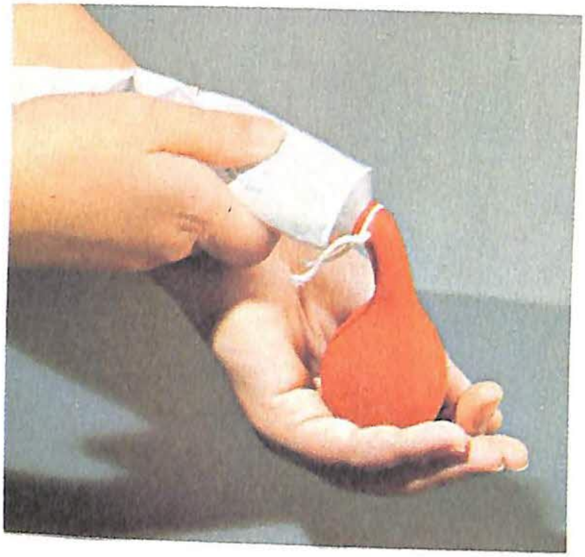
MAKING A MODEL: A Model of the Earth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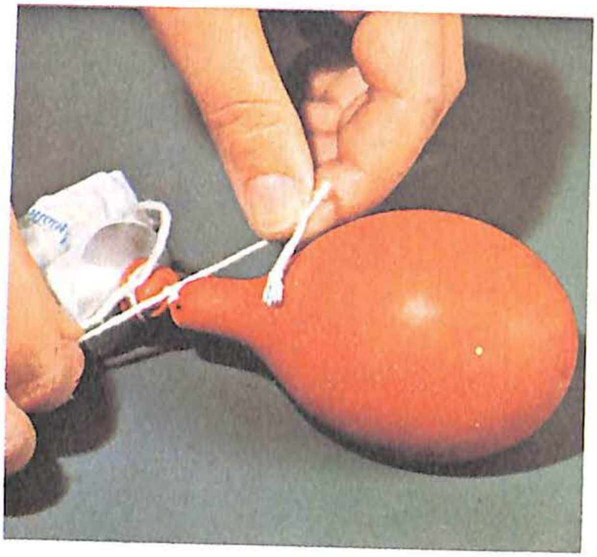
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Needed: a tube of toothpaste, a small round balloon, modeling clay, string

Tie the balloon tightly to the toothpaste tube, as shown. Then squeeze all the toothpaste out of the tube and into the balloon.■ Now tie another string around the neck of the balloon, so that the toothpaste cannot escape.● Untie the first string and remove the balloon from the tube.

Mold modeling clay around the balloon, about an inch deep.▲ Now you have another model of the Earth.

The clay stands for the layer of rock called the mantle. The surface of the clay stands for the Earth's crust. Both the mantle and the crust of the Earth are solid. The toothpaste stands for the core of the Earth. The Earth's core can flow, like toothpaste.

One layer of the Earth has been left out. It is a kind of ocean through which we walk. What is the layer?

▲

■

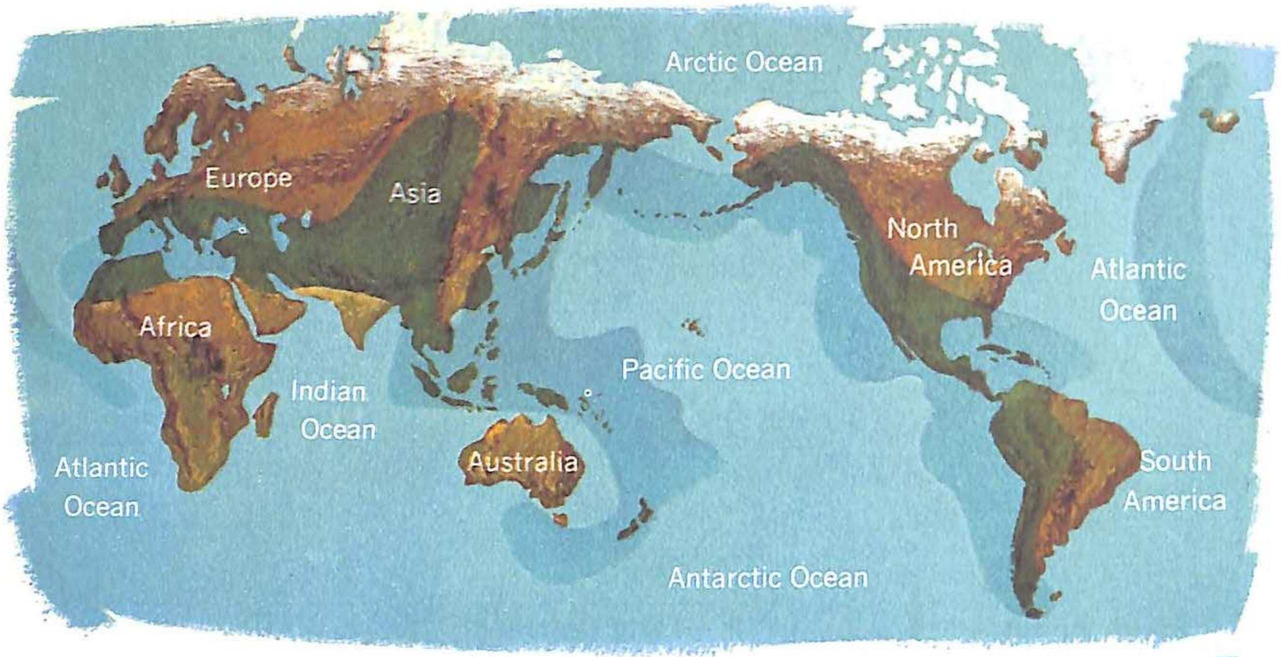
Inside the Earth

Toothpaste is a fluid; it flows. Scientists believe that the center of the Earth is a kind of fluid. Around the fluid center is a thick layer of rock, the mantle, which may be melted in places. The outside surface of the Earth is the crust.

Our model helps us understand that the Earth is not all solid. The crust surrounds hot rock and hot fluid. The rocks in the crust are not smooth and even. They are in broken sections and slabs that rest uneasily on fluid rock.

Sometimes there is a sudden wrenching shift of rock layers. The Earth's crust heaves and trembles, cracks, yawns open. Buildings fall. Whole cities may be destroyed. Anchorage, Alaska, was almost completely wrecked by an earthquake a few years ago. ■ The city of Agadir in Morocco was destroyed in 1959, and parts of Chile suffered severely from earthquakes then. In Iran a tremendous earthquake took place on September 1, 1962. More than 10,000 people were killed.

You might well think that there is nothing men can do about earthquakes. But it turns out, as scientists investigate, that there is something to be done. Scientists have made maps showing where earthquakes happen.



The areas where earthquakes happen are called **earthquake belts.** 🟦

Notice that earthquake belts are along some seacoasts. Some belts are along chains of islands. These belts show where earthquakes are likely to happen. A building put up in an earthquake belt must be able to resist earthquake shocks.

In time, too, scientists may be able to predict *when* earthquakes are likely to take place, as well as where. Scientists are working on this problem now. Then many lives may be saved.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. When scientists study earthquake waves, they learn that the inside of the Earth is
   a. like the crust
   b. not like the crust
2. The layer beneath the crust is called the
   a. core
   b. mantle
3. The inside of the Earth is believed to be
   a. cold
   b. hot

4. From what we know, the Earth is
a. unchanging b. changing

B. Write a paragraph or two on "The Changing Earth."

USING WHAT YOU KNOW

Invent a model of the Earth. Perhaps you can improve on the models you have just used.

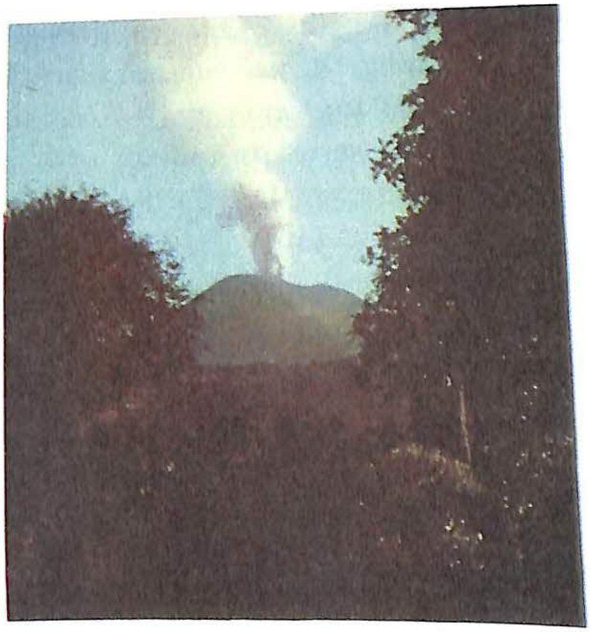
One boy brought in a baseball. The leather cover was the Earth's crust, he said. The layer of cord beneath it was the Earth's mantle. The rubber ball inside the cord binding was the core of the Earth. Was this a good model?

ON YOUR OWN

1. If an earthquake is reported in the newspapers or on radio or television, find the location of the 'quake on the map on page 24. Did the earthquake occur in an earthquake belt?

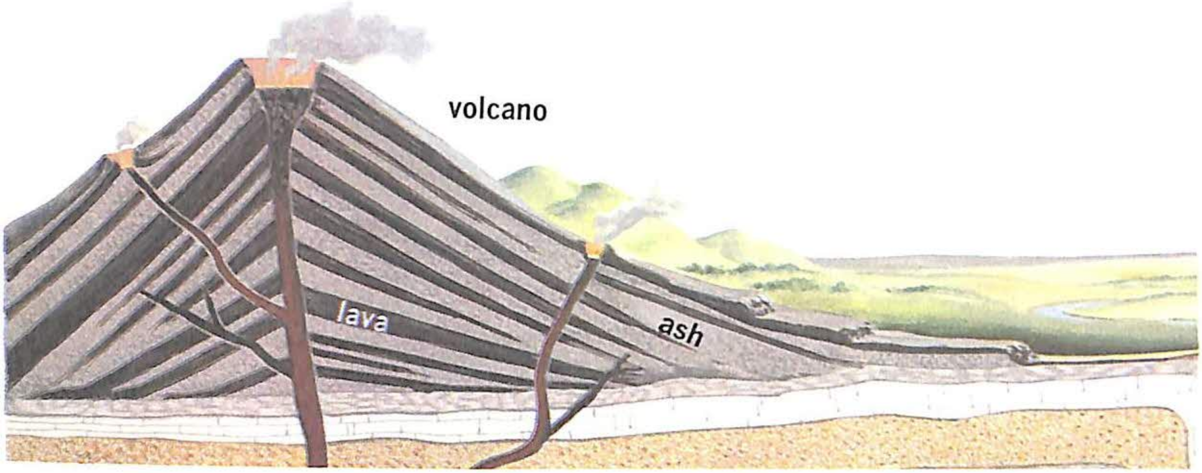
2. Keep a notebook on events in science as reported in the newspapers. Watch for new discoveries which may show that some of the theories and facts reported in this book need to be changed.

4. The Furnace in the Earth



It happened a few years ago, in a quiet Mexican town called Paricutín (pä′rē·ko͞o·tēn′). A farmer saw smoke coming from his cornfield. He hurried over. There was an opening in the ground! Hot gases, ashes, molten rock, poured from the opening, building a mound that grew higher and higher. There was nothing he could do. The Paricutín **volcano** had been born.

Wherever a volcano forms, some rock in the Earth's crust has become



molten. Great heat within the crust has not only melted the rock, but has produced tremendous pressure. (Recall that when a substance is heated it expands, and presses on the substances around it.) If there is a weak spot in the crust, this pressure can force out a stream of molten, flowing rock and hot gases and ashes. If there is no opening, the pressure may break through the crust anyway. It is rather like the pressure you put on a tube of toothpaste, so that the toothpaste gushes out. A tube of toothpaste is one very simple model of a volcano!

Pressure causes hot, melted rock to burst through the Earth's hard crust. The river of molten rock flows along the ground, destroying whatever lies in its way. This molten rock from within the Earth is called **lava** (lä′və).

Lava may cover the land for many miles around a volcano. Over the years lava and ashes may pour out of a volcano again and again, adding layer upon layer, cooling and hardening into a cone-shaped mountain. Lassen Peak in California was formed in this way by a volcano. Now and then it seems as if Lassen Peak might become **active** again, and pour out more lava. But Lassen Peak remains inactive. It just makes rumbling sounds.

Mauna Loa, in Hawaii, is an active volcano. It was not long ago that cinders, ashes, gases, and lava came forth from its **crater** or opening. But Mauna Loa is no longer the fierce volcano it used to be. Alaska has a number of volcanoes, too. Some are active; some just rumble now and then. None seems dangerous.

Only a short time ago the coast of Chile began to shake with earthquakes. At the same time at least five volcanoes burst into life. Many people were killed, and many homes destroyed. Have you read about the fierce volcano, Vesuvius, in Italy? In one eruption it buried three cities 2,000 years ago.

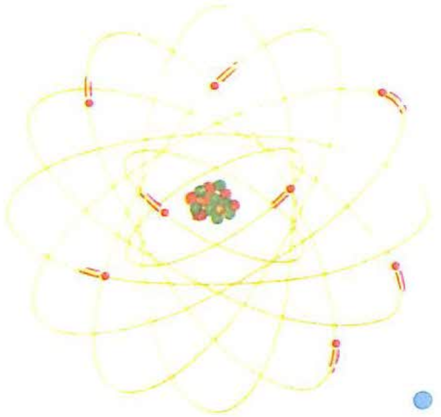
What causes a volcano to heave up? Hot rock bursts through the Earth's crust, pushed by pressure that is caused by heat. What produces this heat?

Heat in the Earth

You may know that to start anything moving, you must use energy. To start a baseball moving, you use the energy of your body. To start an automobile moving, the energy of burning gasoline is used. And when a volcano starts up, heat energy is being used.

Now, energy has to come from somewhere. Where does the heat energy of a volcano come from? It comes from within the Earth, we know. Still, this leads to another question. Where does the Earth get its heat energy?

For a long time scientists puzzled over this question. At last they have found a useful explanation. It is a strange one. To understand this explanation, we must take a look inside the **atom**, the tiny particle of which substances are made.



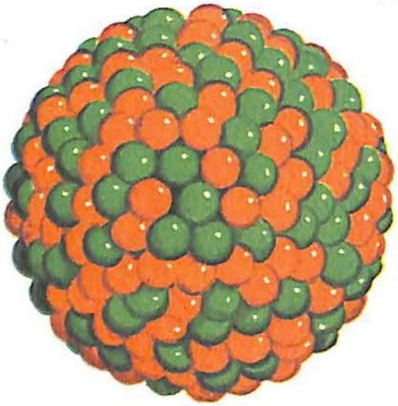
Inside an Atom

Imagine a balloon blown up a bit and filled full of popcorn. It is a model of the center of an atom, a **nucleus** (no͞o′klē·əs). An atom is very tiny, of course. The nucleus of an atom is smaller still. Yet inside the nucleus there are even smaller parts, or particles, somewhat like the popcorn inside the balloon. The particles in the nucleus are mostly of two kinds: **protons** and **neutrons.**

No one has ever seen the nucleus of an atom, not to mention the protons and neutrons inside it. Even so, scientists have managed to find out a great deal about the nucleus. They have *imagined* what a nucleus might be like, according to what they know about it, and have made models of it. Here is a picture of one model of an atom. ● This is a model of an atom of oxygen. The nucleus is in the center. In the model, protons are red, neutrons are green.

oxygen nucleus model

helium nucleus model



uranium nucleus model

■

What are other atoms like? There are protons and neutrons in the nucleus of an atom of helium or of uranium.■ Every atom has a nucleus. Every kind of nucleus but one has in it one or more protons and neutrons. (The hydrogen nucleus has only one proton.)

The protons and neutrons in a nucleus are held together very tightly indeed. Even so, scientists have managed to pry them apart, and to split open the nucleus. When scientists say they have split an atom, they mean they have split a nucleus. Splitting a nucleus is called **fission** (fish′ən).

To break open a nucleus takes tremendous energy, because the protons and neutrons are so tightly bound together. It isn't easy to do. Yet down in the earth beneath your feet the nuclei of certain atoms are breaking up *naturally.* Particles are breaking out of certain atoms now, beneath your feet, in the Earth's crust and mantle. As each nucleus breaks up, it releases a burst of energy. Much of that energy causes *heat.* This is where a great deal of the heat in the crust of the Earth comes from.

The Earth's "Fuel"

The element uranium is a metal. We get it by mining, so we know there is uranium in the Earth's crust. It is scattered not only through the crust but through the mantle as well. This fact is of great importance and benefit to us, as you shall see.

The important thing about uranium in the Earth is this. Every so often a uranium atom gives up particles and rays from its nucleus. It does this naturally. As these particles break out of the uranium nucleus, heat energy is given off.●

These uranium atoms inside the Earth's crust and mantle do not break up quickly. They break up very slowly indeed, over millions of years. Slow as it is, this natural breaking up of uranium atoms makes heat in the Earth.

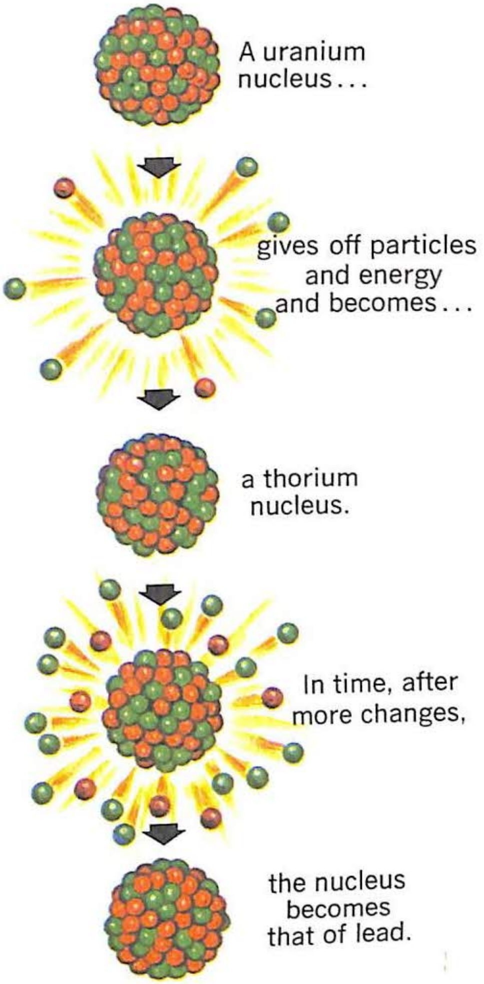
The natural breaking up of an atom is called **radioactivity.** Because uranium breaks up naturally it is said to be radioactive. Some other atoms besides uranium are radioactive. Radium and thorium (thôr′ē·əm), for example, are radioactive.

What happens to a radioactive atom of uranium that gives up particles? It does not remain uranium. In fact, it finally becomes a kind of lead. This lead atom does not break up. It is not radioactive. It is said to be **stable.**

How important is radioactivity? If our Earth's crust did not have the heat energy that comes from radioactivity, it would soon cool down.

The heat given off by radioactivity, within the Earth, gets to the surface of the Earth. Then the heat usually escapes into the air. But sometimes it cannot escape. The heat in one place may be trapped under a blanket of rock. The trapped heat may melt the rock. The melted rock may be pushed up through a crack and spurt out at the surface as a volcano such as Paricutín.

Heat energy gathering under the Earth's surface may lift up the surface itself. Sometimes the melted rock is trapped under rock layers, and slowly pushes them up. Heat given off by radioactivity causes the rock to expand and flow, and push against the layers of rock above. Thus the heat may raise up mountains. Scientists are not sure yet how all mountains are built up, but the heat given off by radioactive atoms is one way.


A uranium nucleus...
gives off particles and energy and becomes...
a thorium nucleus.
In time, after more changes,
the nucleus becomes that of lead.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The breakup of atoms accounts for some of the Earth's
   a. mechanical energy b. heat energy

2. When an atom of uranium breaks up, particles fly out of its

a. electrons b. nucleus

3. The particles and rays which an atom gives off as it breaks up inside the Earth produce

a. heat b. sediment

4. The natural breaking up of an atom is known as

a. radioactivity b. erosion

B. Write a paragraph or two on this topic: "The Earth's Heat."

USING WHAT YOU KNOW

1. What evidence do we have that the Earth is hot beneath the surface of the crust?

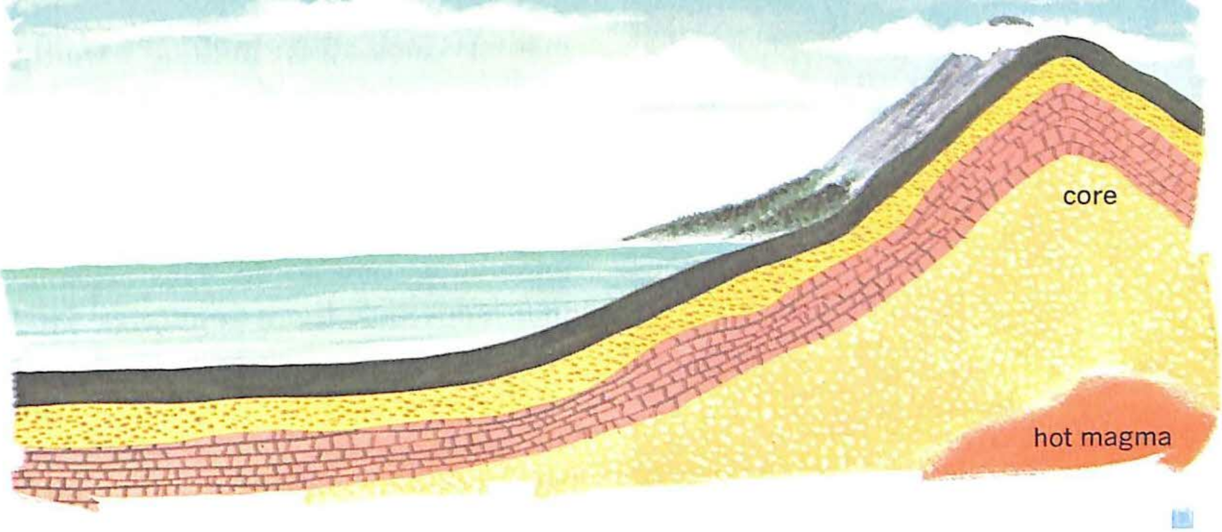
2. Suppose an atom breaks up completely into the particles of which it is made. What is left of the atom?

3. Lava is rich in substances upon which plants can grow. Knowing something of weathering and erosion, try to predict what may happen, in time, to these substances in a valley at the foot of a volcano.

ON YOUR OWN

1. Is there a volcano in your state? Where can you find out about this? in the dictionary? in an encyclopedia? Would you ask your teacher's help, or your librarian's help?

2. The heat of the Earth's crust is due to natural radioactivity and the Sun. The heat of the Earth's core may be due to something else. What may be happening to the rocks in the core? What is above them? (*A hint:* What is the cause of heat in a bicycle tire that is being pumped up?)



5. Up Goes a Mountain

Do you recall how sediment is formed? Rock is weathered into bits and carried by rivers into the sea. Slowly, slowly, layers of sediment form on the sea bottom. Slowly they turn to layers of sedimentary rock, one on top of the other. The layers are like a blanket of rock laid on the sea bottom.

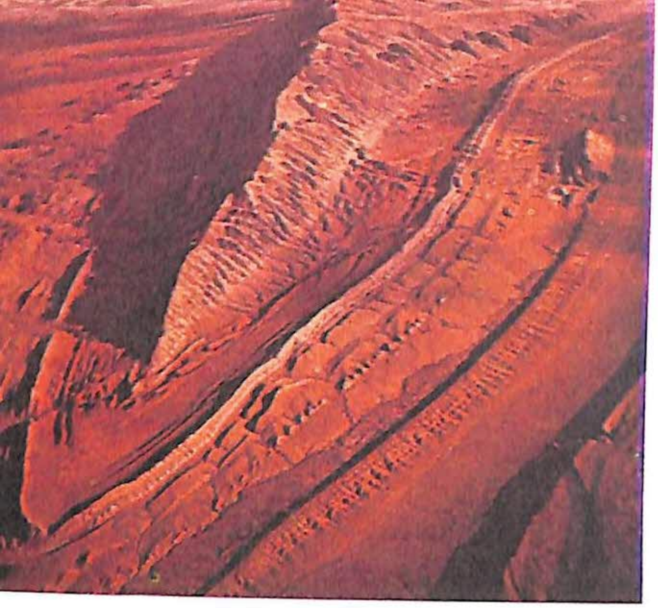
What is happening underneath this blanket? Deep in the Earth's crust and mantle, heat energy is being produced. This heat comes from the radioactivity of certain atoms. Usually this heat energy passes out through the Earth's surface. However, sometimes the heat doesn't escape easily. Sometimes a blanket of many layers of sedimentary rock holds the heat in. Then the heat energy collects in that place. This heat energy has an effect on the rocks nearby.

As the heat collects, it melts the rock. This melted rock is called **magma** (mag′mə). Think of magma as a very thick dough of rock. The heat causes the magma to expand and rise. As it rises, the magma pushes against the blanket of sedimentary rock above it. Slowly, slowly—over thousands of years—heat and expanding magma do their work. Slowly, slowly, the crust heaves up, like a biscuit rising in an oven. The result is a mountain. ■

This is one explanation, or theory, of how one kind of mountain is born. As you shall see, there are other kinds of mountains, and other theories, too.

The Core of a Mountain

As the Earth's crust is heaved up by hot magma, the magma begins to cool. In time the magma becomes cold and hard. This cold, hard rock is the core of the mountain, underneath the sedimentary layers.



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Sometimes the core of a mountain is laid bare so that we can see it. How does this happen? Recall how rocks are worn down by weathering. The Sun's heat makes rocks expand, the night's coolness causes them to contract. Ice splits open the rocks, they break apart, the bits of rock and soil are carried away by rains and rivers. So weathering may wear softer sedimentary rock away, and lay bare the hard core of the mountain. ■

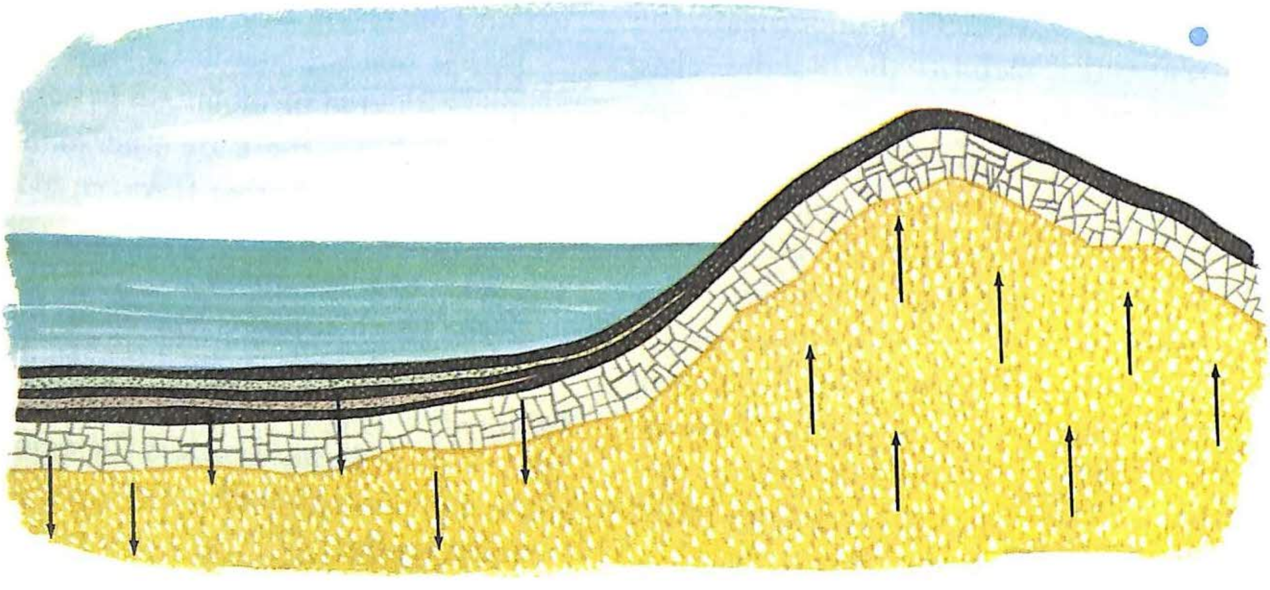
Another Push on the Crust

There is another explanation of how mountains come to be. This explanation holds that there is another kind of push that raises mountains.

This kind of push also begins with the sediment carried by rivers and dumped into the sea.

Imagine all the sediment that is dumped along a seacoast for thousands of years! (In *one* year the Mississippi River pours 500 million tons of sediment into the sea.) In time a tremendous weight of sediment is built up on the ocean floor. It presses on the crust below. It presses on the magma below the crust. ●

The hot magma flows under the crust, and pushes. The weakest part of the crust is heaved up. Slowly a moun-



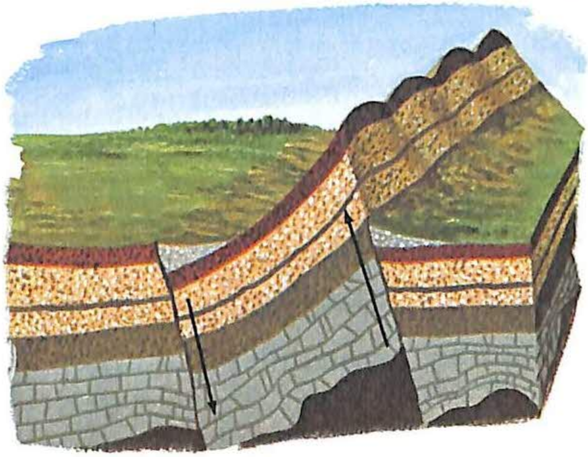
tain, or a range of mountains, is raised.

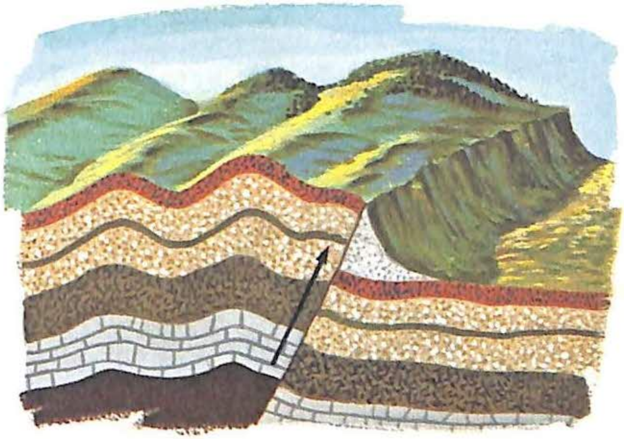
There are still other explanations of how mountains may be made. (Scientists do not yet agree on how mountains are built.) However, scientists are agreed on this: to heave up mountains, energy must be used. Probably the energy used is the heat of the Earth, the heat produced by the radioactive breaking up of atoms. This energy has heaved up mountains. It is heaving up mountains now, as you read this.

If this did not happen, the surface of our Earth would long ago have been worn down smooth and even!

Sometimes the magma pushes against sedimentary rock layers so hard that it bends the layers and makes them look like waves.▲ These wavy layers are called **folds.** Sometimes, instead of bending, the layers break. Then the layers shift to make a **fault.**◆ If this shift happens suddenly, it can cause an earthquake.

◆





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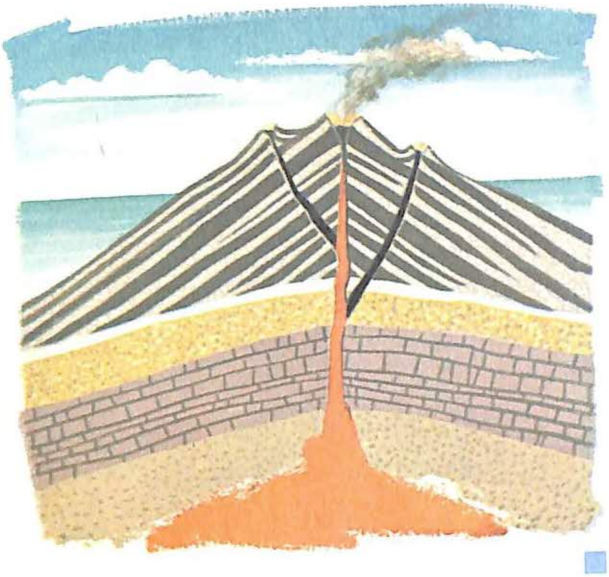
Fossils on Land

Why are fossils found on dry land? Now we can answer this question. Pressure underneath sedimentary rock layers may raise the layers out of the sea. Layers which were at the bottom of a sea or a lake can become dry land. They may even become mountains. So it is that we find fossils of sea creatures on dry land. Sedimentary layers, often containing fossils, have been lifted up above the surface of the water.

Sometimes the forces acting on rock layers have been so strong that the layers have been tilted up on end and broken open. We can sometimes walk over the open end of such layers, and collect the fossils and rocks in it.

There are many different types of mountains on the Earth. But all mountains seem to begin with a push within the crust, a push that seems somehow to come from the heat energy within the Earth.



When Mountains Make Islands

Imagine a break in the Earth's crust deep under the ocean. Melted rock bursts through and begins to form a volcanic mountain *under the sea*. The lava builds the mountain higher and higher, until the top rises above the water. An island has been formed. But the island is really a mountain with its top above water. ■

The islands of our fiftieth state, Hawaii, rose from the sea in this way. Two of the islands have volcanoes that are still active. What is now the soil of Hawaii was once hot melted rock inside the Earth. Poured forth as lava, the rock cooled and hardened. In time it crumbled. Rain and sun turned it into the rich soil which today grows valuable crops.

But every now and then the volcano of Mauna Loa rumbles, deep in the ground, and reminds people that beneath the crust there is melted rock. It also reminds people that all is not quiet within the Earth. There is great heat beneath, great heat that melts rock. And sometimes the melted rock breaks out of its container, the crust. A volcano rising into a mountain reminds us that the Earth is in constant change.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Mountains are worn down by weathering and
   a. erosion b. sedimentation
2. The Earth's heat can be trapped by
   a. sedimentary layers b. weathering
3. Pressure on rock layers is produced mainly by
   a. rising magma b. the expanding core
4. We think that mountains are pushed up mainly by the Earth's
   a. atmosphere b. heat

B. Write a paragraph or two in answer to this question: "How May the Earth's Heat Push Up a Mountain?"

USING WHAT YOU KNOW

1. You have probably heard that radioactivity due to atomic bombs is dangerous. It is. You know that radioactivity is natural, and very important. Write about one hundred words on the importance of radioactivity in the Earth. If your teacher wishes, share your report with your class.

2. Powdered pumice may be bought in a drugstore. Get a hand lens and examine this rough powder which was once lava. How does it differ from soil?

ON YOUR OWN

1. Get a piece of pumice stone (a drugstore may have it). Place it in a pan of water. What happens? Can you find out why this happens? Do you know of any other kind of rock that behaves this way?

2. Not all islands are volcanic. For instance, some islands have been made by animals living in the sea. Find out how coral islands and coral reefs are made. Where will you search for the information?

6. Treasure Beneath Your Feet

Do you know Robert Louis Stevenson's famous story, "Treasure Island"? If you do, you will remember that the boy, Jim Hawkins, and the pirate, Long John Silver, searched for treasure on an island. When at last they found it, there were bars of gold and heaps of coins.

However, there is treasure all around us that most people don't know about. In truth, all the Earth's crust is treasure. In the crust are not only gold and silver but copper and aluminum, iron for making steel, and many, many other materials. In the crust are the substances that make up soil, on which plants and animals live. There is coal, oil, and natural gas in the Earth's crust too.

In the Earth's crust are the substances we need for living. What greater treasure could there be?

Some of the substances in this treasure are called **minerals.** Minerals are elements and compounds which are part of the Earth's crust. Gold is a mineral, for example, and so is salt. Both are found in the Earth. There are minerals in the crust, the magma, the mantle, and the core. Rocks have many minerals in them. In fact, rocks can be identified by the minerals in them. Let us see why this is so.

The Look of Fire-Formed Rocks

When magma flows out of a volcano, it forms lava, as you know. ■ Of course most magma doesn't reach the Earth's surface. It cools and hardens below the surface and forms rock.

Any rock formed from fire-hot magma is called an **igneous** (ig′nē·əs) rock. *Igneous* means "formed by fire." Thus, pumice is an igneous rock that cooled above the surface. Granite is an igneous rock that cooled below the surface. But both kinds of rock were formed from hot magma. ■

You might think that scientists would agree that igneous rocks such as granites came from magma. Not all geologists agree, however, on this theory about granites. Some geologists hold the theory that igneous rocks like granites were formed in a different way. They think that many granites were formed when hot fluid moving up from inside the Earth met rocks already there. These hot fluids seeped into the rocks and changed them into granites. It is important to know that scientists do not agree all the time. They are likely to agree on facts, if the facts have been checked by different scientists. (It is a fact that granite rocks are in the Earth.) Scientists do not always agree on the explanation of facts, however. This is one example: Geologists do not agree on how granite rock is formed.

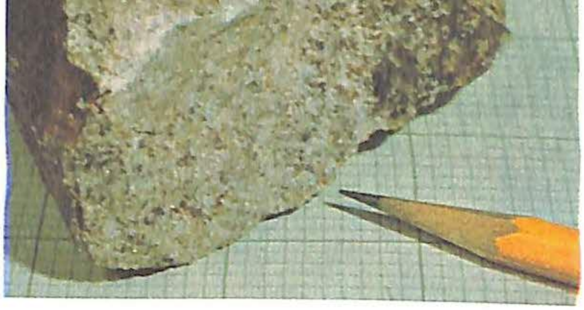
If you begin to collect igneous rocks, you will soon discover that there are many different kinds. Some look blue, others look rose-colored. Some sparkle like diamonds, others are a shiny black. Yet all have been formed from magma. Why do they look so different, then?

Why Rocks Look Different

For one thing, different rocks have different minerals in them. Remember that there are many minerals in magma, many different elements and compounds. Rocks that have different minerals in them usually look different.

For another thing, rocks may look different even when they have the same minerals. For instance, two rocks may have different *amounts* of the same mineral. This granite block has in it a good deal of pink feldspar.● But another granite rock with just a little of feldspar in it does not look pink at all.▲ Here is a dark granite rock that contains a lot of a black mineral called hornblende (hôrn′blend).◆ The lighter-colored piece of granite beside it has hornblende in it too—but only a little.

Here is another reason why rocks may look different. Some of the minerals in a rock may be in the form of **crystals.** For example, this is the mineral quartz.★ Can you see that each of these quartz crystals has six sides? Crystals may be large or small, and of different shapes. You can see this for yourself. Make some crystals of your own by doing the investigation on the next page.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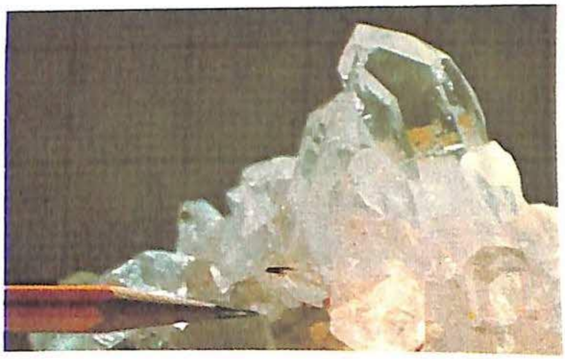
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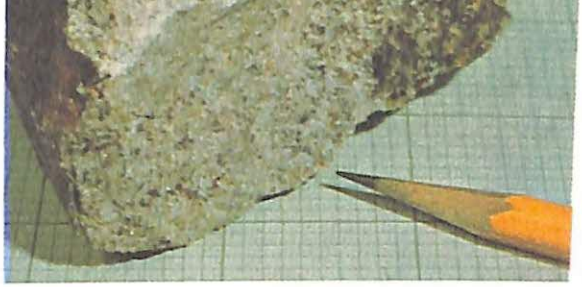
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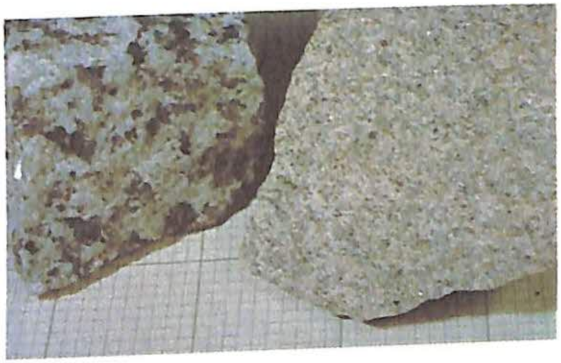
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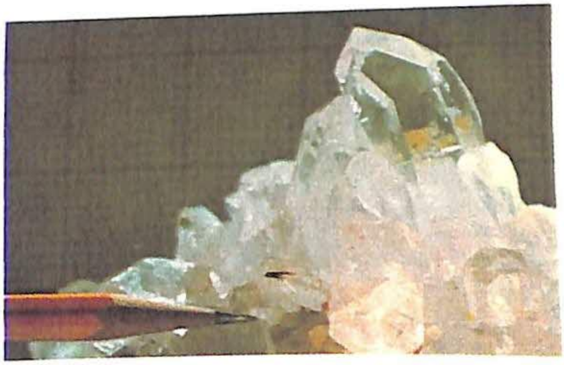
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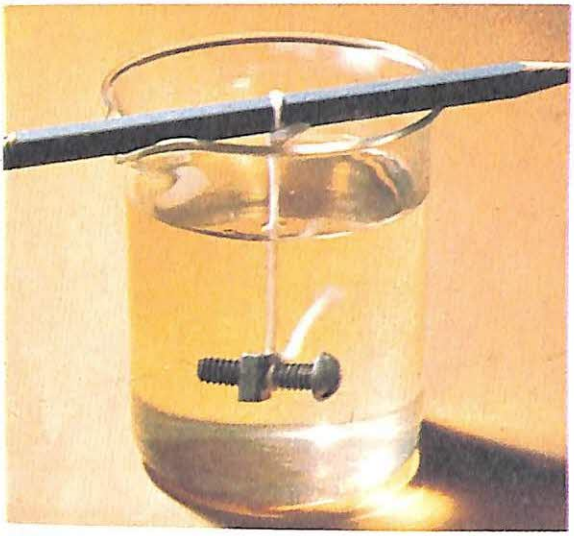
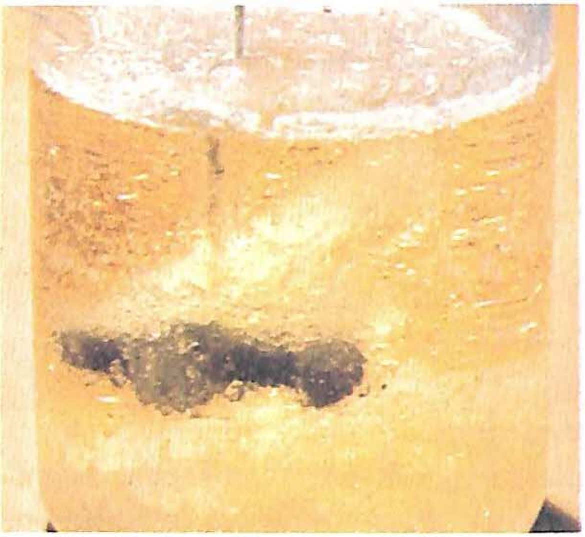
AN INVESTIGATION into Making Crystals

■





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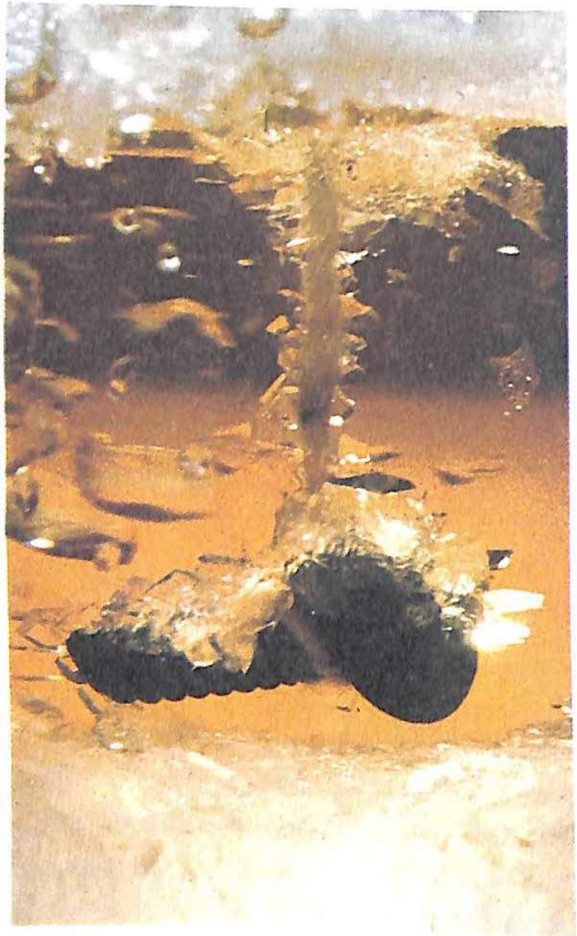


Needed: a Pyrex beaker, a teaspoon, a pencil, a piece of string, a bolt or large nail, a hot plate, water, $\frac{2}{3}$ cup sugar

Put $\frac{1}{4}$ cup of water in the Pyrex beaker and heat it on the hot plate. When the water is boiling, add $\frac{2}{3}$ cup of sugar. Add the sugar slowly and stir constantly until all the sugar has dissolved. Then turn off the hot plate.

Now tie the bolt or nail to the string, and hang it in the beaker as shown. ■

Let the glass of sugar solution cool. Do not disturb it while it is cooling. In time crystals will begin to form. Observe where they form first and how they grow. ●

Here is what happened. ▲

Additional Investigation: Try making crystals of salt by evaporation. Compare them with sugar crystals.

A Problem in Cooling

Some rocks have large crystals in them. Some have small crystals. Some rocks have crystals so small that the rocks look almost glassy.

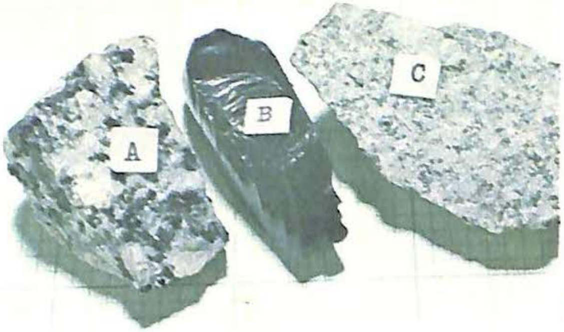
Here are three such rocks. ■ They are all igneous rocks formed from magma. But each rock cooled at a different speed. One cooled underground, very slowly. One cooled near the surface, not as slowly as the one underground. One cooled on the surface, quickly. Examine the picture carefully. Which rock do you think cooled most slowly? Which cooled a little faster? Which cooled the fastest? (Answers are on page 40.)

Igneous rocks can indeed have many different colors and shapes. Even rocks that look alike at first may turn out to be different when examined closely. This is one reason why some people like to collect rocks; there are surprises.

At the end of this book there is a guide to collecting rocks. Why not look through it? If you were to collect fire-formed rocks only, you would still be able to have a large collection. But there are two other general kinds of rocks. As you will see, it is possible to tell which kind is which.

The Look of Sedimentary Rocks

Sedimentary rocks have their own beauty and meaning. They are the fossil-carriers, as you know. Most of them are formed from sediment carried by streams and rivers and oceans. Think for a moment how many different sorts of sediment there must be. It won't surprise you, then, that there are many different sorts of sedimentary rocks. Let's look at a few of them.



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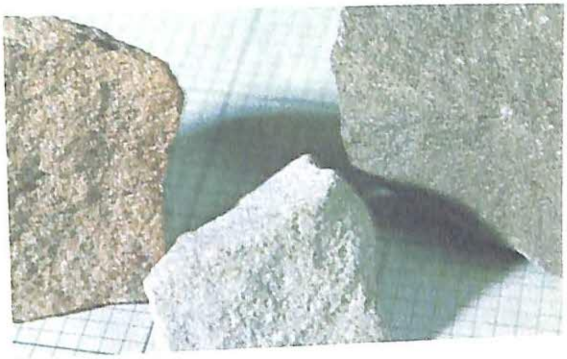

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Sand, for instance, can be pressed into a sedimentary rock called sandstone. As you can see, sandstone comes in different colors. ● Perhaps you have seen one of the old brownstone houses made of brown sandstone. Most sandstone is not very hard and is easily weathered by the chemicals in city air. Yes, the stone of a building may be broken down by weathering, like the stone of a mountain. Perhaps you have observed this.

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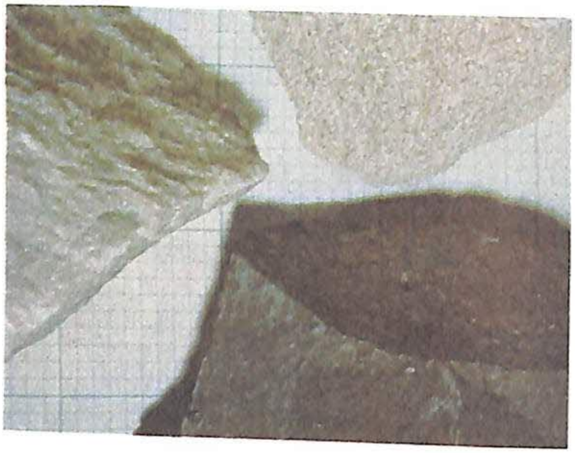
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Out in the country you may see pieces of the sedimentary rock called shale used in stone walls. ■ Or it may be used in flagstones. Shale can be gray-blue or reddish-brown, or other colors. Wet a piece of shale and smell it, for a clue as to what it comes from. It will smell like clay or mud! Shale is formed from pressed mud or clay, squeezed into sedimentary rock.

Answers to a problem in cooling on page 39

Cooled most slowly: Rock (a), coarse-grained granite.

Cooled a little faster: Rock (c), fine-grained granite.

Cooled the fastest: Rock (b), glassy black obsidian.

Another kind of sedimentary rock is limestone. ● As you see, some limestones are light in color. They are often used for building. Limestone will bubble if placed in some vinegar; it is made up of calcium carbonate.

The rock called chalk is also made of calcium carbonate. But this is not the chalk you find in the classroom. The chalk you use at the chalkboard is not made up of shells. The sedimentary rock, chalk, is made up of the shells of tiny animals. ▲ The chalk cliffs of Dover, in England, are actually billions upon billions of these tiny shells.

The animals that once lived in these shells lived in the sea. When the animals died and sank to the bottom, their shells were pressed into chalk.

If you've ever seen plum pudding, you may agree that this rock looks something like it.◆ But here the plums are pebbles, in a pudding of sandstone. This rock is called puddingstone.

Where are these sedimentary rocks to be found? Almost everywhere—but here are some clues. Look where a river or stream has cut its banks. Look where man has cut a road. There layers of sedimentary rock may be open for you to see. Or you may be able to get pieces of various rocks from a stonemason or dealer in building materials.

The Look of Changed Rocks

There are some rocks that are neither sedimentary nor igneous.

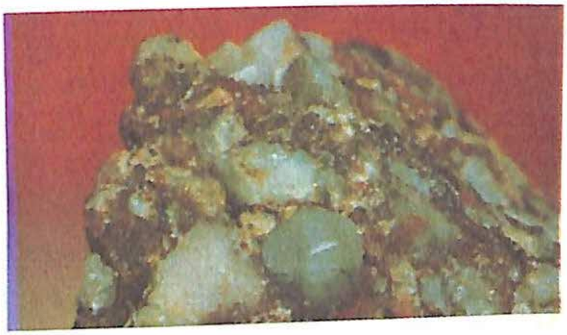
Look at the rock called slate.★ Perhaps you have a chalkboard made of slate. Wet a spot on it and you will smell the odor of mud or clay. Does this remind you of something? Moistened shale smells like mud or clay, too.

Slate and shale are not the same. Slate is harder than shale, for instance. But they are related. Slate rock is made from shale rock. Here is how it happens.

The magma within the Earth is always pressing against the rock layers of the crust above it. The layers above are pressing down. Sometimes the tremendous pressure and heat squeezes and cooks the rock until it becomes a different kind of rock. When shale is heated and pressed over many years, it changes into slate.

This new kind of rock is called **metamorphic** (met′ə·môr′fik) rock. The word *metamorphic* means "changed in form." Slate is a metamorphic rock.

Another metamorphic rock is marble.◈ As you see, there are different kinds of marble; it is a beautiful rock,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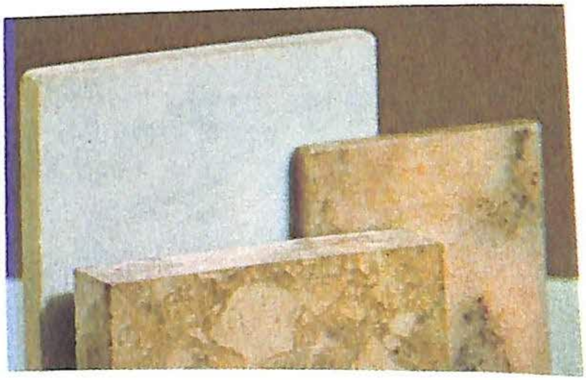
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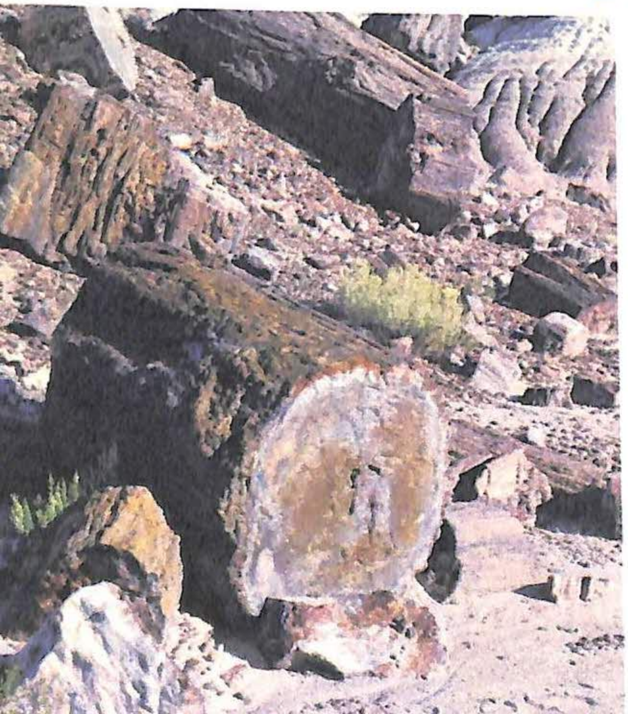
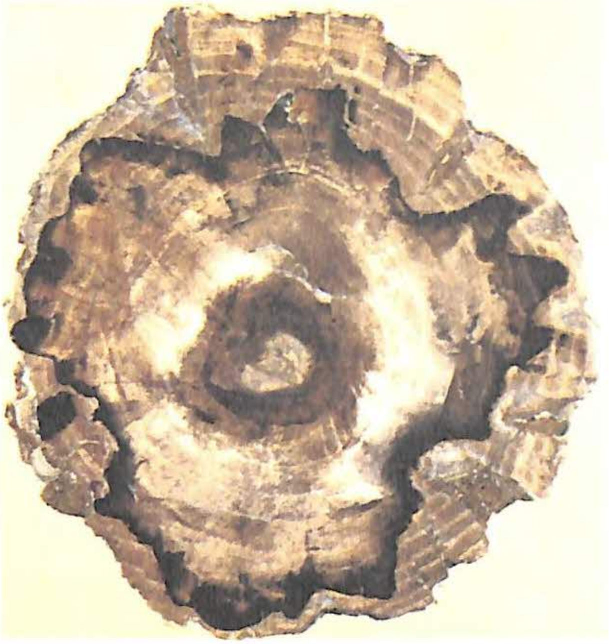
often with crystals in it. You may see statues, columns, even table tops of marble. The Lincoln Memorial in our nation's capital is of white marble.

Place some chips of marble in vinegar and the vinegar will bubble, because carbon dioxide gas is being produced. This is a clue that marble is made of calcium carbonate. Do you recall meeting calcium carbonate before? Back on page 40 this same test showed that limestone is made of calcium carbonate. Can you guess now what sedimentary rock is changed to form the metamorphic rock marble? It is limestone. Pressure and heat may change limestone to marble.

The Look of Living Things Changed to Rock

Strangely enough, there are rocks that did not begin by being igneous or sedimentary. Some rocks began with living things.





In the Petrified Forest, in Arizona, the trees are made of stone. ■ (*Petrified* means "changed to stone.") But once, a long time ago, those trees were alive.

Usually, when a tree falls, tiny living things go to work on it. The tree decays. Insects and worms change it into powdery material that makes rich soil. The trees in the Petrified Forest, however, fell where water flowed over them, thousands of years ago. In fact, the minerals in the water began to take the place of the wood in the trees. Bit by bit the trees of wood became trees made of minerals—trees of stone. The minerals colored the petrified wood in different ways. ● But you can see that this stone really was once a tree. Count the rings of growth. One ring was formed each year.

BEFORE YOU GO ON

Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Granite is a kind of rock classed as
   a. igneous b. sedimentary
2. Limestone is a kind of rock classed as
   a. igneous b. sedimentary
3. Shale is a kind of rock classed as
   a. igneous b. sedimentary
4. One kind of metamorphic rock is
   a. marble b. sandstone
5. The rocks we see in the ground are in the Earth's
   a. mantle b. crust

USING WHAT YOU KNOW

1. Below, on the left, is a list of common rocks. On the right are the three groups in which common rocks are classified. Try to classify each rock correctly by naming its group.

Rock

slate
marble
limestone
puddingstone
shale
chalk
granite

Group

igneous
sedimentary
metamorphic

2. You are given two highly polished stones. One of them is said to have come from a tree. The other is said to be an igneous rock. How might you tell one from the other?

ON YOUR OWN

1. Make crystals of different substances. Follow the directions in the Investigation on page 38 for making crystals of sugar, but use substances such as copper sulfate, Rochelle salts, or alum instead of sugar. (Don't put your fingers in your mouth when handling copper sulfate.)

Crystals and Crystal Growing, by Allan Holden and Phylis Singer, published by Doubleday, New York, 1961. You may find this very useful book a bit difficult in some parts, but the directions for growing crystals, on pages 93 to 106, will be helpful.

2. You may already have begun studying rocks in the field, and collecting rocks. (Remember that ways of collecting and identifying rocks are given at the end of this book.) Ask your teacher if you may exhibit your collection. Or each pupil might bring one rock or fossil to class to start a school collection.

7. The Main Concept: The Changing Earth

Billions of years ago our Earth and Sun were formed out of a cloud of hot gas, some scientists think. The Earth became a hot ball revolving around the Sun.

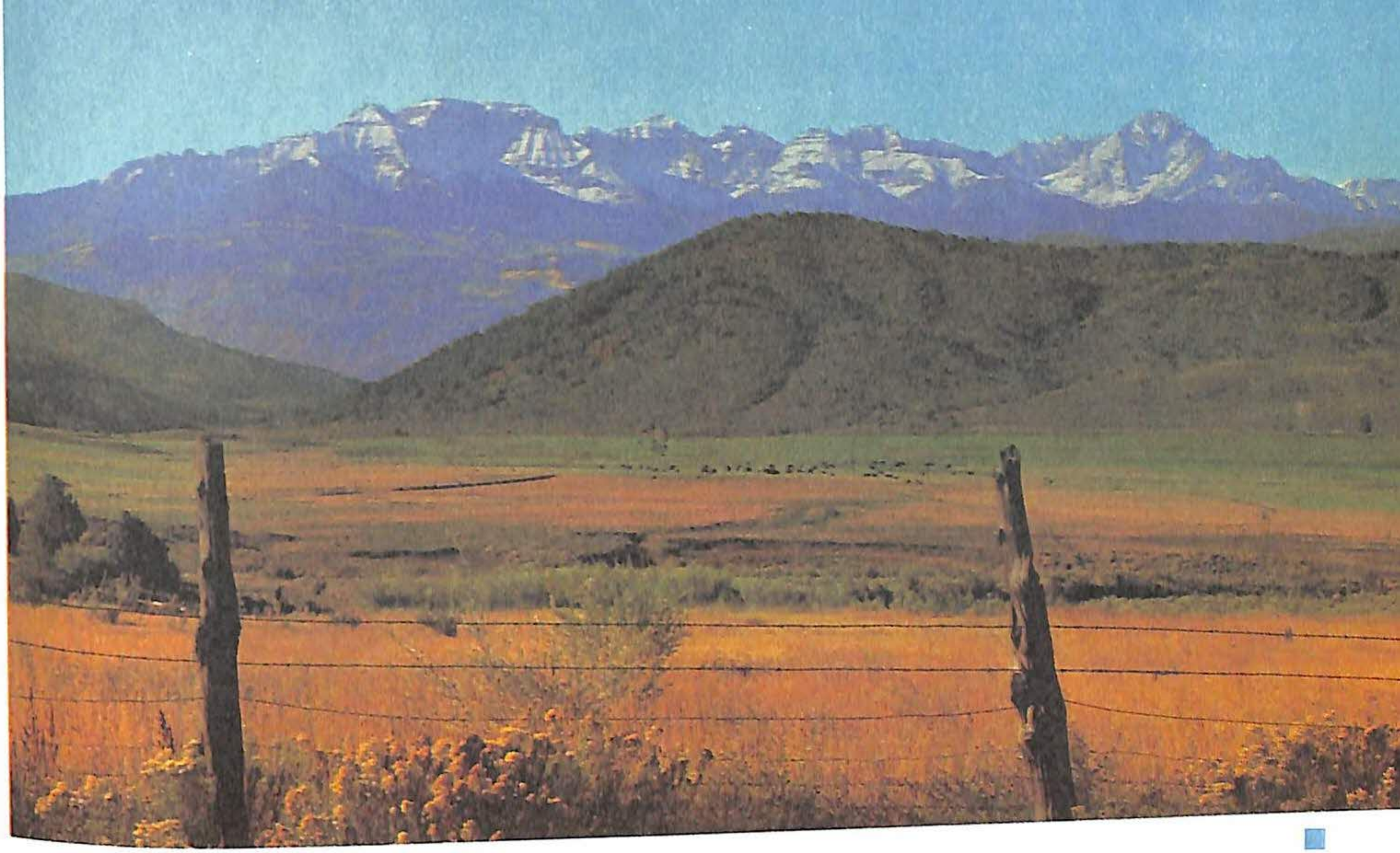
Over billions of years the Earth formed and cooled. The ocean of air that now surrounds the Earth began to form. As this **atmosphere** cooled, water vapor in the air changed to water. From this water came the first seas. The first seas were not salty, it seems.

The crust cooled slowly. One volcano after another burst out on the young Earth. Magma bubbled to the surface and cooled. The magma formed layer upon layer of rock as it cooled.

The rocks began to weather as the Earth cooled. Heat and cold cracked them. Rains carried stones, pebbles, and bits of rock into the valleys. There the first soil was formed. Some of the weathered rock was carried into the seas, and formed the first sedimentary rocks. The very early sedimentary rocks have no fossils in them. There are no fossils probably because there was no life on Earth then.

Mountains were worn down. Sediment poured into the oceans. As the sedimentary layers got deeper and heavier, they pressed harder on the magma below.

Even as the sedimentary layers were being laid down, new mountains were rising up. What kind of energy heaved up mountains, melted magma, caused volcanoes to spout out lava? It was the energy of radioactivity.



■

There are radioactive elements, such as uranium, in the crust and mantle. As the nucleus of a radioactive element splits, heat energy is produced. There is energy enough to lift mountains.

The process goes on even now. The land is being worn down. The layers of sedimentary rock are growing, and pressing on the magma. The blanket of sedimentary rock is trapping the heat of radioactivity. Somewhere else, to ease that pressure, the hot expanding magma is lifting the crust. Another mountain range is beginning to form. We expect these changes to go on for a long time, because the Earth is still a young planet. Its mountains have been worn down many times. They will be worn down many times more.

Understanding the concepts of science, we can look back to the past and explain what happened. But we can do more. We can look forward and predict the future. We can predict, for instance, what will happen to rock that is exposed to heat, cold, and rain. Today the Rocky Mountains have the shape of upside down **V**'s. They are young mountains. ■ What will their shape be like a million years from now? Make your prediction!

One thing is very clear. The Earth is always changing.

Fixing the Main Concepts

TESTING YOURSELF

A. Test your understanding of important concepts in this unit by doing these problems.

1. A fossil of a fish is found on high land. How did it get there?

2. A sidewalk has cracks in it. A huge slab of igneous rock showing through soil is cracked. What force might have cracked both the sidewalk and the rock?

3. A sedimentary layer has good-sized stones in it. Was the river which carried the stones flowing quickly or slowly? What is your reasoning?

4. Which kind of rock is harder, granite or limestone? Why?

5. Why is there a good chance for sedimentary rock to build up along the seacoast?

6. We sometimes find that a river lengthens where it empties into the sea. The Mississippi River, for instance, has added to its length near New Orleans. ■ How do you explain this?

B. Test your understanding of concepts in this unit by using each of these key words and phrases in a sentence.

crust
mantle
core
weathering
erosion
radioactivity
earthquake
volcano
crystal

sedimentary
metamorphic
igneous
proton
magma
Λ-shaped mountain
∩-shaped mountain
fossil
nucleus

C. Test your knowledge with this quick check.

1. The action of heat and ice on rock is

a. erosion

b. weathering

c. radioactivity

d. mountain building

2. Water and wind wear away bits of rock and soil. When this happens, which one of these is going on?

a. erosion

b. weathering

c. radioactivity

d. mountain building

3. The results of radioactivity are all but one of these:
   - a. particles are given off from the nucleus
   - b. rays are given off from the nucleus
   - c. heat energy is produced
   - d. sediment becomes rock

4. You would expect to find a fossil in
   - a. igneous rock
   - b. metamorphic rock
   - c. sedimentary rock
   - d. magma

5. We can be certain that 100 years from now
   - a. the Earth will be the same
   - b. the Earth will have changed in some way
   - c. the Rocky Mountains will have been completely eroded
   - d. no sedimentary rock will be forming

ON YOUR OWN

1. If you haven't already done so, find a place for your rock collection. First read pages 346–347 in this book. These pages tell you how to collect your rocks, and how to keep them.

2. There is a theory that mountains actually float in the rock below them. What can you find out about this?

FOR YOUR READING

1. *My Hobby Is Collecting Rocks and Minerals,* by David E. Jensen, published by Childrens Press, Chicago, 1958. A book to help you start your collection.

2. *Rocks, Rivers, and the Changing Earth,* by Herman and Nina Schneider, published by W. R. Scott, New York, 1952. Rivers run and rocks are broken down as weathering and erosion do their job. This is a story well told.

3. *Collecting Rocks, Minerals, Gems, and Fossils* by Russell P. MacFall, published by Popular Mechanics Press, New York, 1963. This is a well-written and well-illustrated book that has something in it for the experienced collector as well as for the beginner.

GOING FURTHER

An Invitation to Investigation

You have already done some investigations. (For example, on page 38 you investigated how to make sugar crystals.) There are many such investigations in this book. They are meant to help you learn to investigate.

Here, however, at the end of this unit, we offer you a problem for which there is no answer in this book. Make up your own way of tackling the problem. You can find an answer if your investigation is carefully thought out.

There is one such investigation at the end of each unit in this book. Each investigation may take from a week to a month to do. Here is the first one.

An Investigation

You have already grown sugar crystals. At what temperature do crystals grow best? in cold water? in water at room temperature?

Plan an investigation to answer the question.

How will you tell where the crystals are growing best? by their number? by their size? or is there another way? It will be interesting to see how you decide this.

STATE INSTITUTE OF EDUCATION
Govt. of W. Bengal

CONCEPTUAL SCHEME

When matter changes from one form to another, the total amount of matter remains unchanged.

Unit Two

ABOUT 100 BUILDING BLOCKS

(Text pages 50–89)

UNIT CONCEPT
In chemical and physical change, the total amount of matter remains unchanged.

Children begin, through their investigations, to discover that an orderly combination of only relatively few kinds of invisible atoms can account for the infinite variety of substances in their familiar and visible world. In the building up of molecules of compounds from atoms of elements, they see that no atoms can be gained or lost, nor can there be a gain or loss when a compound is broken down. From this, they infer the broad concept that in all ordinary chemical reactions matter is neither gained or lost. They also discover that the infinite variety of compounds can be better understood by grouping them in a few broad classes from which their chemical composition and general properties can be predicted.

A VIEW OF THE UNIT

A Preview of the Concepts

This unit introduces the children to the world of the chemist and the geologist. From the Earth, its rocks and soil, its water and air, come all the substances they can touch, taste, smell, and see. Chemistry is at work all around them every day in the rusting of bridges, the erosion of rocks, the dissolving of substances and recombining of them. Chemistry in the elementary grades is a "quiet" subject. It does not require complicated retorts, corrosive acids and bases, explosive combinations, or dangerous sources of heat energy. A burning candle or rusting steel wool can teach children the concept of oxidation; vinegar and limewater can teach the concept of reactions between acids and bases. Iron rust, water, and carbon dioxide can be used to illustrate the three states of oxides—solid, liquid, and gaseous. By working with the simple substances that take part in or are the result of chemical reactions, children are able to make tentative groupings of substances according to their chemical properties. This is simple chemistry; it is also safe chemistry from which the law of conservation of matter can be inferred by every child; that is, in a chemical change matter is neither gained nor lost.

Chemical Tests

Children also acquire some useful techniques of analysis as tools for understanding matter. Testing of substances is one of them. Chemical reactions enable children to test inferences and explanations, a key activity of scientists. For example, the limewater test shows them that carbon dioxide is released when oxygen combines with carbon; it can be put to useful purpose in analysis of the process of oxidation in living things or in determining whether a rock was formed from deposits of calcium made by once-living things. The litmus paper test enables them to distinguish between acids and bases and neutral substances.

Equations

By writing simple word equations, all children begin to see that no matter is gained or lost in building up compounds (synthesis) or in breaking them down (decomposition). Suggestions for extending the concept in certain sections of the unit give an opportunity for interested children to learn a few chemical symbols and formulas and to analyze simple equations. From these the concept that all atoms in molecules of substances taking part in a chemical reaction must appear in the product is reinforced, a further illustration of the law of conservation of matter.

From such simple chemistry, children gain a new view of the Earth as consisting of about 100 building blocks, seven particularly common. A comprehension of this unseen micro-world of atoms and their diversities of molecular combinations lays a groundwork for understanding, in later units, the work of living cells as chemical factories in all living things.

Acids and Bases in the Classroom

Carbonic acid, from carbon dioxide and water, and other acids mentioned in this section are safe for children to handle. Use concentrated vinegar where a stronger acid is needed. Hydrochloric or sulfuric acid should not be used in the elementary classroom as they are very corrosive to skin and clothing, and their safe use requires extreme caution and careful techniques of handling. Similarly, limewater is a safe base for children to handle, whereas lye cannot be recommended. Even in using these same acids and bases, it is desirable to encourage children to train themselves in proper laboratory techniques. With a little practice, most children can learn how to remove the lid and hold the bottle and its cover (or stopper) in one hand to avoid contamination of the stopper by laying it down. This leaves the other hand free for using a drinking straw as a pipette to secure drops of acid or other liquids for testing. Placing a finger over the open end of the straw after it has been immersed in the liquid allows withdrawal of a strawful. Slight release of the finger, with practice, permits release of the liquid, drop by drop, to enable accurate measurement by a count of drops.

A Supply of Limewater

Testing for carbon dioxide, a frequent activity in this textbook, may require a generous supply of limewater. It can be obtained in liquid, tablet, or powder form from the druggist. A refined hydrate of lime, calcium oxide (CaO), used for plaster finishing of inside walls of buildings, can also be used. Add the oxide to water, stirring until no more oxide will dissolve; then wash hands thoroughly. Pour the solution through filter paper to remove excess solid. The storage bottle should be kept full so that the solution will not absorb carbon dioxide from above the liquid.

Periodic Table of the Elements

Not infrequently, individual children, on their own, find out about the Periodic Table. A dozen or so common elements are introduced in this unit; a few others will be met in later units. If you have some familiarity with the Table, or a wall chart of it, you may wish to rule up a blank table and have it duplicated so that children may place in it the elements as they encounter them. Useful background and information is given in pages 445–48 of *The Physical World*, Second Edition, by Richard Brinckerhoff, Burnett Cross, Fletcher Watson, and Paul F. Brandwein, Harcourt, Brace & World, 1963. If you wish to attempt overlays for overhead projection, details and background can be located in *Elements of the Universe* by Glenn Seaborg and E. G. Valens, Dutton, 1958. Children are often fascinated by the grouping of elements, which gives an orderly explanation; but comprehension of why the elements are grouped as they are requires greater knowledge of atomic structure and chemical properties than any but the child with a strong interest in chemistry is likely to acquire in this grade.

SUPPLEMENTARY AIDS

Films

All films and filmstrips are in full color, and the filmstrips are especially recommended for their excellence. Names and addresses of suppliers are on page F–25.

Evidence for Molecules and Atoms (19 min.), E.B.F. Demonstrates that though unseen, molecules and atoms in solids, liquids, and gases can be proved to exist. Atoms are building blocks of molecules. Modern science is based on the existence of atoms and molecules. (Intermediate, Junior High)

Explaining Matter: Atoms and Molecules (14 min.), E.B.F. Shows atoms as building blocks of matter that form molecules. Explains elements, compounds, and mixtures. (Intermediate)

Explaining Matter: Chemical Change (11 min.), E.B.F. A chemical change takes place when atoms from the molecules of two or more substances join with one another to form molecules of entirely different substances. Important changes take place in everyday situations—burning, digestion, and plant photosynthesis. (Intermediate, Junior High)

Filmstrips

Chemical Changes (42 frames), S.V.E., 1958. Demonstrates difference between chemical and physical change. Shows expression in formulas, how to produce and prevent chemical changes. (Intermediate)

What Things Are Made Of (43 frames), S.V.E., 1958. Explains the properties of elements, illustrates what compounds are. Simple experiments show building of compounds from elements; also building mixtures. (Intermediate)

The Atom (37 frames), McGraw-Hill, 1952. The atom is the basic building block of the universe. Shows the three parts of an atom; formation of molecules; nuclear energy released through fission; nuclear energy. (Intermediate)

Changes All Around Us (50 frames), McGraw-Hill, 1951. Presents concept of chemical change; simple chemical experiments and safety rules in the laboratory; oxygen's role in burning; limewater test. (Intermediate)

Changing Ores into Metals (42 frames), McGraw-Hill, 1953. Most metallic ores are compounds; metal is obtained by separating compound into elements; iron, copper, lead, zinc, and nickel ores. Experiments show how compounds are separated into elements. (Intermediate)

Oxidation (42 frames), McGraw-Hill, 1953. Deals with basic scientific principles; matter is neither created nor destroyed; Lavoisier's experiments; burning involves the combination of oxygen with substance. (Intermediate)

Putting Sulfur to Work (42 frames), McGraw-Hill, 1953. Sulfur and products are backbone of chemical industry—how mined, characteristics, many uses of its compounds. (Intermediate)

What Are Elements and Compounds? (42 frames), McGraw-Hill, 1953. Explains atoms in an element, make-up of atom (protons—neutrons); building a compound; differences of elements and compounds. (Intermediate)

World's Matter Supply (37 frames), McGraw-Hill, 1952. Matter found as elements, compounds, and mixtures. Kinds of matter put in usable form by physical or chemical change. Conservation of resources necessary for future life. (Intermediate)

Composition of Air (37 frames), Jam Handy, 1961. Explains what an element is; what a compound is. Importance of oxygen, nitrogen, and carbon dioxide in air. In air each retains its own properties and becomes a mixture. Experiments suggested. (Junior High)

Science Reading Table

The starred titles are especially recommended for their content and readability. Addresses of the publishers are on page F–24.

All About the Wonders of Chemistry by Ira M. Freeman, Random House, 1954. Basic facts outline what chemistry is and what it is about. Application of chemistry is described in steel production, agriculture, medicine, and other industries and fields of study. (Advanced)

Chemistry: First S–T–E–P–S by Keith Gorden Irwin, Franklin Watts, 1963. Introductory survey of chemistry in familiar living and nonliving things. Included are a few simple experiments which will assist accurate concept development at this initial stage of study. (Average)

Exploring Chemistry by Roy Gallant, Doubleday, 1958. Describes the development of chemistry through the ages and the contributions of famous men of science. Frontiers of chemistry today, including the use of chemistry in the space age, give further emphasis to the continuing accumulation of knowledge. (Advanced)

Fun With Science by Mae and Ira Freeman, Random House, 1943. New copyright, 1956, by Mae and Ira Freeman. Paperback published 1958 by TAB Books, an affiliate of Scholastic Magazines, for distribution through Arrow Book Club. Laws of physics are demonstrated through simple experiments clearly described and illustrated with photographs. Children will gain understanding of such phenomena as gravitation, inertia, sound, chain reaction, water pressure, and jet action. (Average)

The True Book of Chemistry: What Things Are Made Of by Philip B. Carona, Children's Press, 1962. Elements and compounds, atoms and molecules, chemical symbols and formulas, and the difference between chemical and physical change are described. An introduction to chemistry as a basic scientific study. (Easy)

°*Physics: Its Marvels and Mysteries* by Daniel Q. Posin, Whitman, 1961. Simple and witty explanations of difficult science topics, including flight, magnetism, behavior of liquids and gases, heat, sound, light, electricity, and the atom. Easy experiments and questions are directed to the curiosity of children. (Average)

The Story of Chemistry by Mae and Ira Freeman, Random House, 1962. Molecules and atoms are described with simple examples. Facts about elements, compounds, and chemical change are included. Reference to commonplace items and experiences help to clarify difficult concepts. (Easy)

What Is Chemistry? by Daniel Q. Posin, Benefic Press, 1961. A miniature encyclopedia on atoms, molecules, elements, chemical change, and recent discoveries and uses. Many facts are presented and a few simple experiments are described. (Average)

°*Your Wonderful World of Science* by Mae and Ira Freeman, Random House, 1957. Very simplified description of the physical and chemical characteristics and properties of the Earth, Sun, weather, rocks, air, water, and heat. Concept development is slowly paced but interestingly organized. (Easy)

▶ INTRODUCING THE UNIT

What happens when you tear a piece of paper? Or stir a spoonful of sugar into a glass of water? Or boil water and turn it into water vapor? Do you think a chemical change has taken place that makes the smaller pieces of paper, or the sugar which seems to have disappeared, or the water different from what you started with? Children are doubtless aware that the pieces of paper are still paper, that the sugar can be recovered by evaporation, and the water vapor condensed by directing the steam against a cold object. If any are skeptical, encourage an investigation. Now, let's suppose you burn the paper or the sugar. Is the black substance you get different? (Yes.) Is iron rust the same as iron? (Of course not.) But there is a big question: Has matter been lost when the paper and sugar are burned? Has matter been gained when iron rusts? What are your best guesses? This unit gives you a chance to test your thinking about matter and its changes.

(*Text pages 52–55*)

SUBCONCEPT

A molecule is the smallest particle of a substance which retains the properties of the substance.

Section 1: MOLECULES

Children derive understanding of the nature of molecules and of chemical properties.

Introducing the Concept

What's in this paper bag? You can recognize it by its smell, but first let us guess what it is. It can be bought at the grocery. (Apples are suggested, but any fruit or odorous vegetable will do.) Holding the bag in midair, encourage the children to narrow their ideas to the possible. After all guesses are recorded, permit a volunteer to smell the bag without looking into it. How do you know, without looking, what is in the bag? (The odor of apples.) Would every bit of apple smell like an apple? If we could divide the apple until we could no longer see it, would one of these divisions have the smell and the taste of apples?

What is the smallest part of a substance we can have? What do we mean by properties of a substance?

Developing the Concept

How do you know what a substance is? While keeping a lemon concealed, ask for two volunteers for a blindfold test. Waft a half lemon under the nose of each. What is it? Cut the lemon into very small pieces, and repeat the test. Allow volunteers to taste. How do you know it is a lemon? (Its lemonlike properties—smell, feel, taste.) The first volunteers will enjoy helping you give the test to another set of volunteers, this time with an orange. Does it smell, feel, taste like a lemon? (No.) A lemon is every bit a lemon, an orange every bit an orange because each little bit has the properties of either a lemon or an orange. What do we mean by *properties?* Clarification of the chemist's use of the term might be reinforced by dictionary reference and comparisons with other uses of the word. There may be several substances that give a lemon its lemonlike properties. What is the smallest part we can have of each substance? (A molecule.) What is a molecule? Children may now read their textbook in preparation for the investigation on page 53. Selected volunteers may set up the equipment.

What is an element? Which of these two containers holds sugar? What property enables you to choose? (Taste.) If you heat sugar in a test tube, do you still have sugar? (No.) How can you find out? Check the properties of the substances in the test tube. One is water and the other is carbon (text page 52). How can we find out if carbon has the properties of sugar? (Taste it.) Can the carbon be changed by continued heating? (No.) After reading the text following the textbook investigation, children should infer that carbon is an element, but that sugar must have more than one element in it. If you heat iron and copper and they do not change, what kind of substances are they? (Elements.) Atoms of one kind make up a molecule of an element; atoms of more than one kind make up a molecule of all other substances. The 92 elements that are found naturally, plus 11 others made by scientists in the laboratory, are the building blocks of matter.

Children should be able to combine the ideas of this section in answering these questions: Can you have molecules that consist of only one kind of atom or only of different kinds of atoms? (Both.) What do all molecules have in common? (Atoms.) What do all substances have in common? (Molecules.)

Equipment and Materials

. . . paper bag of apples

Children gain an understanding of chemical properties and infer the existence of molecules.

Processes emphasized

Observation
Investigation
Measurement
Hypothesizing
Categorizing

Equipment and Materials

See text page 53; also the Teacher's Manual for *Classroom Laboratory 5.*

An element is made up of one kind of atom, with a definable set of properties; atoms are the building blocks of matter.

Equipment and Materials

. . . salt
. . . sugar
. . . test tube

Extending the Concept

Combining the building blocks. How many words are in your dictionary? You could make an "educated guess" by counting the words per page and multiplying by the number of pages. How many letters in our alphabet? (26.) Over a half-million English words have been built from these 26 letters. The chemist's alphabet is four times larger. All the natural and artificial compounds of the 103 elements add up to over 500,000 different substances. Can you name some and bring some examples?

Equipment and Materials

. . . teaspoon
. . . 2 white saucers
. . . dropper
. . . ink

How big is a molecule? Ask the children to predict the number of molecules in one drop of ink. Write these on the board for later reference. Ask for assistants to help you carefully. Measure a teaspoonful (50 drops) of water into a white saucer. Add one drop of ink to the 50 drops (1 teaspoonful) of water. Has the color spread evenly? (Yes.) Would it be true if we said that the drop of ink has been divided into 50 parts? Add one drop of this solution to a teaspoonful of water in a second white saucer. If the color spreads evenly, how many parts of ink should we have now? (50 × 50.) What part of the original drop of ink is this? (1 divided by 2,500 gives the answer in a fraction.) Let children use decimals if they are not confused by them.

Continuing the process with a third saucer yields 1 part color to 125,000 parts water. In reality, if you write the digit 1 followed by 20 zeros, you will have represented the approximate number of molecules in one drop of water. It may spark children's imaginations to imagine a water drop as big as Earth—only then its molecules would be about as large as walnuts.

To count the molecules on the head of a pin would take you 200 years, even if every person in the United States were to help you. A hundred million molecules in a row measures but one inch. No wonder it took so long for scientists to be sure what tiny particles make up the substances on Earth!

Equipment and Materials

. . . hydrogen peroxide
. . . vinegar
. . . rubbing alcohol
. . . starch
. . . sugar

Chemical shorthand. Some children may have seen chemical formulas, such as H_2O and CO_2, and are able to infer that the symbol H stands for hydrogen, O for oxygen, and C for carbon. But what does the small figure 2 (subscript) stand for? (Two atoms of hydrogen to one of oxygen in the H_2O formula, but two atoms of oxygen to one atom of carbon in the CO_2 formula.) Hold up the hydrogen peroxide bottle. This substance has one more atom of oxygen in its formula than water does. How shall we write it? (H_2O_2.)

The following table, which you may wish to place on the chalkboard, gives the number of atoms in four different substances.

Substances	**C atoms**	**H atoms**	**O atoms**
vinegar	2	4	2
alcohol	2	6	1
starch	6	10	5
sugar	12	22	11

What three elements are in all of the substances? How can we write their formulas? ($C_2H_4O_2$, C_2H_6O, $C_6H_{10}O_5$, $C_{12}H_{22}O_{11}$.) Does the table (and the formulas) suggest why each substance has different properties? (The number of atoms and the way they are combined differ.)

(*Text pages 54–55*)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. b 4. b

Using What You Know. 1. a. nitrogen, hydrogen; b. sugar, starch. 2. Atoms, because most molecules have more than one atom. If a molecule has only one atom, the atoms and the molecules are the same size.

Section 2: BREAKING DOWN A MOLECULE

(*Text pages 55–59*)

SUBCONCEPT

Compounds can be broken down into the elements of which they are composed.

Processes emphasized

Investigation (and design)
Reporting
Predicting
Hypothesizing
Theorizing
Using the chemist's language

Equipment and Materials

. . . coffee can
. . . sugar cube
. . . Sterno or hot plate
. . . mirror or kitchen knife

Children begin to realize that chemical composition of a substance can be analyzed by breaking it down into its simpler components.

Introducing the Concept

Review children's understanding of what an element is. Hold up a sugar cube. Is sugar an element? How can you find out? By crushing? (No.) Why not? (Each granule has the properties of sugar.) You can find out with the equipment you see.

Place one or two teaspoonfuls of sugar in a coffee can and set over heat source. As the sugar starts to melt, a volunteer may hold a chilled mirror over the can. What do you see? (Drops of water.) Where did they come from? Some children may be able to deduce that H and O atoms from the sugar regrouped into water molecules. The water isn't at all like sugar, is it? Continue heating until the sugar turns black. What is the black substance? (Carbon.) Is it an element? (Yes.) What have we learned about the chemical makeup of sugar? (It is composed of an element and water.) Is water an element? (No; it is composed of hydrogen and oxygen, as most children are able to tell you.) Develop the term *compound* as meaning a substance *composed of* two or more other substances. Sugar is a compound.

What will a molecule of a compound consist of? Can we break down other compounds to find out what they are made of?

Children retest heating as a means of decomposing a compound.

Equipment and Materials

See text page 57; also the Teacher's Manual for *Classroom Laboratory* 5.

Developing the Concept

How can we break down (decompose) mercuric oxide? After a reading and discussion of the text, plan the investigation with the children. You may first wish to encourage them to design their own plan. Here a compound is separated into its elements. As you plan, explicate the safety cautions in the investigation (page 57). For all investigations requiring a heat source, it is desirable to work on a heat-resistant surface, such as an asbestos mat, or to provide a potholder or saucer on which to set hot objects.

Word equations help to describe a chemical reaction.

How is a word equation useful? Ask a volunteer to write on the chalkboard a sentence description of what happens when sugar is broken down into carbon and water. Another child may write a sentence describing the decomposition of mercuric oxide. Underneath the sentences write:

$$\text{sugar} \longrightarrow \text{water} + \text{carbon}$$
$$\text{mercuric oxide} \longrightarrow \text{mercury} + \text{oxygen}$$

Why is the equation useful? (It saves time and is a clear statement.) What does the arrow mean? What does the plus sign mean? What do the equations refer to: elements, compounds, atoms, molecules? (Molecules, i.e., sugar molecules yield water molecules and carbon molecules.) Why must you have more than one molecule on one side of the arrow or the other? Why does the arrow point in the direction it does?

Chemical properties help in identifying a substance.

Properties of elements. From your text investigation you should be able to list some properties of elements, such as mercury or oxygen. To test your students you could make riddles, as for example:

I am a colorless, odorless gas.

I am found combined with mercury, hydrogen, carbon, and with many other elements. What am I? (Oxygen.)

Extending the Concept

A compound needs more than one. Can you think of substances other than the two you have investigated that are composed of just elements? One you drink every day. Another you breathe out. Another you often sprinkle on hard-boiled eggs. Some of you may wish to investigate some of the simpler elements and compounds and make models of them. Information and ideas may be found in some of the readings suggested at the beginning of the unit or through references in the library.

Equipment and Materials

- . . . test tubes
- . . . carbon rods
- . . . 6-volt dry cell
- . . . battery clips
- . . . battery jar or beaker
- . . . wire
- . . . sodium carbonate or sodium sulfate
- . . . wood splints

Separating the elements in water. The electrolysis of water is a classic example of decomposition of a compound into its elements. It is not difficult for upper-grade children, particularly the "science prone," to set up and demonstrate. (Figure 12-1, A *Sourcebook for Elementary Science.*) Sodium carbonate (baking soda) or sodium sulfate hastens the reaction. Use a 6-volt dry cell as a source of current. More specific directions may be found on page 197 of A *Sourcebook for Elementary Science.*

As current decomposes the solution, the children can see for themselves that gas collects twice as fast in one tube as in the other. They can infer that the tube with the larger amount of gas contains hydrogen. Encourage the children to find and demonstrate the simple and safe tests for hydrogen and oxygen. (Oxygen: a *glowing* splint thrust into the tube bursts into flame; hydrogen: a *burning* splint produces a loud pop.) You may find it useful to witness a "practice run" before any children's demonstrations.

(*Text pages 58–59*)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. b 4. a

Using What You Know. 1. It is breaking down; oxygen is being given off, leaving water. 2. Carbon and oxygen.

(*Text pages 60–64*)

Section 3: BUILDING UP A MOLECULE

SUBCONCEPT
Compounds are built up from elements.

Children, in investigating how oxygen combines with other elements, become acquainted with a large group of chemically important compounds.

Processes emphasized
Investigation (and design)
Hypothesizing
Theorizing
Predicting
Model building
Reporting

Equipment and Materials
. . . steel wool
. . . iron nails
. . . copper strip
. . . aluminum strip
. . . test tubes or olive bottles
. . . food coloring
. . . cork or wood chips
(See also the Teacher's Manual for *Classroom Laboratory* 5.)

Introducing the Concept

Display in full view the materials listed in the margin. Do you think we can make a compound with these materials plus a common element in the air? What is this element? (Oxygen.) Which materials will combine most easily with oxygen so that we can see the compound? After the children have agreed on iron, stuff a small wad of steel wool into the ends of two test tubes or tall olive bottles. One container is dry. Label this CONTROL. The other is wet on the inside. Invert each in an inch of water. Coloring the water makes it easier to see any change in water level. Encourage a prediction of results. Why are the mouths of the tubes underwater? (To see if oxygen in the air will combine with the iron.) What should happen if it does combine? (The water will rise in the tube.) Explain that it may take several days to see results. Let's read our text and try a quicker way of getting oxygen, as in the investigation on pages 60–61.

What is an oxide? Why are steel bridges painted? How can we write a word equation for building up an oxide? Do most metals form oxides?

Developing the Concept

Children see how oxygen combines with iron to form iron oxide, a compound having properties different from those of the combining elements.

Planning to make iron oxide. The text investigation calls for the use of hydrogen peroxide. How can you show that it releases oxygen? Pour a small amount over a warmed cookie sheet or polished metal pan and note the bubbles of oxygen. Or warm about an inch of it in a test tube, insert a glowing splint, and watch the splint burst into flames, a test for oxygen. As many children as possible, working in groups, should have an opportunity to see for themselves the "quick rusting" method of the text investigation.

Other metals combine with oxygen to form oxides; oxides can be identified by their chemical composition.

Other metal oxides. Do other metals "rust"? That is, do they form oxides? What do you think is the substance that causes a green coating on the wood under copper screens or on copperware? (Copper oxide.) Aluminum oxide, mentioned on page 62, has properties different from iron oxide. It forms a hard surface and keeps oxygen from the aluminum metal underneath it. How is iron oxide different? (It flakes off the surface.) The zinc coating on galvanized nails eventually turns to a white powder and the iron under it will rust. What do you think the white powder is? (Zinc oxide.) Where did the oxygen come from to make these oxides? (The air.)

Rusting may result from rapid release of oxygen in a chemical reaction.

Equipment and Materials

- . . . steel wool
- . . . bleach
- . . . vinegar
- . . . 2 glasses
- . . . measuring cup
- . . . teaspoon

"Instant" rusting. Are the test tubes, set up as you began the section, showing any signs of rusting? (Probably not.) Encourage patience. You may wish to demonstrate rapid rusting resulting from the production of oxygen from a chemical reaction. Use new, fine, steel wool. Do not use scouring pads as they contain scouring chemicals. In each of two glasses place a one- to two-inch wad of steel wool. Add $\frac{1}{2}$ cupful of cold water to one glass and label it CONTROL. To the same amount of water in a second glass add 1 teaspoonful of vinegar and 3 of bleach (sodium hypochlorite or Clorox). Very shortly the steel wool appears rusty. "Why so quickly?" your "assistant" chemists may say. The iron in iron oxide (rust) comes from the steel wool. Where did the oxygen come from? Water? Let's look at the control. Is the steel wool rusty? (No; at least, not yet.) Where must the oxygen have come from? Place the formula for vinegar, $C_2H_4O_2$, and for sodium hypochlorite, NaOCl, on the chalkboard. Recall that hydrogen peroxide, H_2O_2, had "extra" oxygen. Children infer that when vinegar and bleach are mixed, "something happens" to release some of the oxygen so that it can combine with the steel wool. The chemical reaction is complex; actually the two compounds chemically react and produce oxygen and sodium chloride (table salt), among other compounds.

Rusting can be prevented by keeping oxygen and iron atoms from combining.

Why are iron bridges painted? How does rusty iron compare with unrusted iron? Children see that, close up, rust is flaky and weak. Would you rather ride over a rusted bridge or a painted one? The children may recall having seen a bridge and other metal supports being painted bright red. Actually, this is "red lead," a form of lead oxide, which has already taken on all the oxygen it can hold. Since the red lead can take up no more oxygen, it keeps air from getting to the metal underneath. The steel girders are protected against the weather until there is time to cover them with a further protective finishing coat of paint.

Extending the Concept

Equipment and Materials

- . . . Vaseline
- . . . household oil
- . . . clear nail polish
- . . . tin can
- . . . tin snips
- . . . sandpaper

Inhibiting oxidation. How would you keep a compound from forming? (By keeping the elements that form the compound apart.) How would you keep iron oxide (rust) from being made? (By keeping oxygen in the air away from iron and steel.) Ask a child to bring in his bicycle. Turn it upside down and examine the metal surfaces. What do you see? Rust? Oil or grease? Paint? How does oil, grease, or paint prevent rust? Use tin snips to cut small squares from a tin can. Scratch or sandpaper to remove some of the plating. Coat these squares separately with household oil, Vaseline, and nail polish. Place these and one uncoated square in water. What happens to the coated surface? The uncoated surface?

Children infer that any coating that keeps oxygen from a metal surface will retard or stop rusting or corrosion. How would you keep garden tools from rusting?

Equipment and Materials

. . . 2 jars
. . . iron filings

The effect of moisture and heat on speed of rusting. From their investigations, children should be able to infer that moisture increases the speed of oxidation. Would you then expect more or less rusting in a desert or in a humid climate? (Less in desert.) In winter or summer? That is, does rusting take place faster when it is hot or when it is cold? Wet the inside of two jars and shake iron filings against the sides. Cover. Place one in a warm place and the other in the refrigerator. Check in two days. Why is there less rust in the refrigerated sample? Children should infer that heat increases and lack of heat decreases the speed at which molecules move; hence, the chemical change in rusting is related to the speed at which molecules move.

(*Text pages 63–64*)

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. a 4. a B. When they combine with oxygen, they undergo a chemical change, becoming oxides.

Using What You Know. 1. iron oxide → iron + oxygen; water → hydrogen + oxygen; aluminum oxide → aluminum + oxygen.

On Your Own. Children should, in their research, discover that: (1) Tin does not form tin oxide readily; iron does; (2) "galvanized" means plated with zinc, which forms a hard, protective, zinc-oxide coating that keeps oxygen from the iron; (3) stainless steel is iron with another metal melted in it that keeps oxygen from combining with the iron.

Section 4: TWO COMMON GROUPS OF COMPOUNDS

(*Text pages 65–68*)

SUBCONCEPT
Compounds may be grouped by their chemical properties.

Children, by a simple chemical test, discover two other large groups of common compounds, acids and bases. They continue to develop ability to classify, an important activity of the scientist.

Introducing the Concept

Processes emphasized

Investigation (and design)
Observation
Hypothesizing
Theorizing
Predicting
Testing

Write the word *opposites* on the board. What does this word make you think of? Write the children's responses, e.g., night-day, boy-girl, sweet-sour, black-white, etc. Add *acid-base* to the list. Can you name an acid? What is one property of an acid, such as lemon juice? (It tastes sour.) Do you think tasting is a safe way to test for an acid? It is well to establish early in science work that tasting is never a safe test; no tasting of anything, unless it is a known food product, should be permitted.

What is an opposite of an acid? How can we find out whether a substance is an acid or something else? Are there substances that are neither acids nor their opposites?

Developing the Concept

Children discover that litmus paper is a chemical indicator.

Equipment and Materials

- . . . paper nut cups
- . . . teaspoons
- . . . colored construction paper
- . . . litmus paper
- . . . lemon juice

(See also the Teacher's Manual for *Classroom Laboratory* 5.)

The change in color of litmus paper. Encourage children, working in groups, to carry out the investigation for changing the color of litmus paper (text page 66). First, however, to establish that litmus paper has special chemical properties, provide each group with a paper nut cup containing 1 to 2 teaspoonfuls of lemon juice, a few strips of pink and blue construction paper, and a few strips of litmus paper. What happens when you dip an end of construction paper into the lemon juice? An end of litmus paper? Children, of course, discover that lemon juice changes only the blue litmus paper. They infer that blue litmus paper has a special chemical property that is affected by a chemical property of lemon juice. Now, let's test other substances also by trying the investigation on page 66.

Children establish the chemical test for distinguishing acids, bases, and neutral substances.

Equipment and Materials

See text page 67; also the Teacher's Manual for *Classroom Laboratory* 5.

Acid or base? or neither? After reading their text, children next engage in the "Investigation into Testing for Acids and Bases" (text page 67). The children will gain deeper insight into classification by chemical testing if you can provide opportunity for all to test various household substances for acid, base, or neutral reactions. Encourage testing until each child is certain which color of litmus paper turns color in the presence of an acid and which turns color in the presence of a base. For clarification and reinforcement, also encourage the writing of a word equation for the reactions:

blue litmus + acid ⟶ pink color
pink litmus + base ⟶ blue color

What happens if pink litmus is placed in an acid? Blue litmus in a base? (No change.) Why must we test a substance with both pink and blue litmus paper, if the first color we use does not change?

blue litmus + nonbase ⟶ no change
pink litmus + nonacid ⟶ no change

A change in acid or basic properties may be tested by litmus paper.

Changing back. Can an acid be changed into a base? Can it be changed back again? Children should be able to infer that the mixing of opposites will cause a change and that more of one "opposite" than another may show up in the litmus paper test. Several volunteers may be encouraged to demonstrate. One child summarized in this way:

Acid + **Base** + **Acid**
Litmus: pink ⟶ blue ⟶ pink

The sting you feel in many insect bites (ants or wasps, for example) is due to an acid from the insect's stinger. What might you apply to change the acid? (A base, such as household ammonia.)

Extending the Concept

Neutralizing a base or an acid. If an acid and a base are mixed, can a point be found when litmus paper does not change color? Encourage children to blend dilute ammonia drop by drop with vinegar and test with litmus paper until pink and blue remain unchanged. Acid and base have *neutralized* each other. What is the substance now? Evaporation reveals it to be a salt, ammonium acetate.

Equipment and Materials

- . . . dropper
- . . . dilute ammonia
- . . . vinegar or lemon juice
- . . . litmus paper

Since the use of hydrochloric or sulfuric acid and concentrated bases cannot be recommended for elementary grade children, the recovery of the more common salts cannot be investigated. The following are safe substances, all salts. Encourage interested children to test on their own and to report for neutral litmus reaction: sodium bicarbonate (baking soda); sodium carbonate (washing soda); sodium tetraborate (Borax); sodium stearate (soap); calcium sulfate (plaster of Paris); calcium carbonate (chalk). What three letters do the names of these substances end in? (*–ate.*) The acid which combined with a base to make the salt ends in *–ic*. Thus carbonic acid helped to form the carbonates, boric acid the borates, sulfuric acid the sulfates, and stearic acid the stearates. Children may be able to predict that any substance whose chemical name ends in *–ic* will turn blue litmus pink and that a substance ending in *–ate* will show change in neither pink nor blue litmus paper. Not all salts end in *–ate*, however; e.g., sodium chloride.

Other indicators. Litmus is a vegetable compound extracted from lichens. Are there other plant indicators that will show acid-base reactions? Refer children to pages 112–14 of *Discovering Chemistry* by Elizabeth K. Cooper, Harcourt, Brace & World, 1959, for indicators made from flowers and from red cabbage. An acid turns the deep-purple cabbage juice red; a base turns it yellowish green. Encourage children to test with a homemade indicator for the reaction of household acids such as boric-acid powder (in solution), lactic acid in sour milk (can be quickly made by adding a teaspoonful of vinegar to evaporated milk), citric acid in citrus fruits, tannic acid in tea, coffee, tomato juice, or stewed rhubarb.

Making an important acid from two common compounds. Carbonic acid is made of two compounds the children already know—water and carbon dioxide. The first we have; the second we can readily make (text page 61). The collecting tube of the generator is set upright and half full of water. Be sure the delivery tube stays under water during gas collection. Place 2 tablespoonfuls of sodium bicarbonate and 2 tablespoonfuls of vinegar in the carton generator. What will the compound formed be? Acid? Base? Neither? Test with litmus paper for confirmation that an acid has been formed. What is this acid? (Carbonic acid.) This acid forms as water vapor and carbon dioxide combine in the air —but only in small amounts. It is an important agent of erosion (Unit One) where plants and lichens are gaining a foothold on rocks. It also helps to speed up rusting (oxidation) of iron, as on unpainted bridges.

Equipment and Materials

- . . . generator, as described on text page 61
- . . . litmus paper
- . . . bicarbonate of soda
- . . . vinegar

(Text page 68)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. a 4. b 5. b

Using What You Know. A base; bases will cause pink litmus to turn blue.

On Your Own. A weak acid.

(Text pages 68–73)

SUBCONCEPT

Chemical reactions are a dependable means of testing the presence of a substance.

Processes emphasized

Investigation (and design)
Observation
Hypothesizing
Theorizing
Predicting
Reporting
Using the chemist's language

Section 5: AN IMPORTANT TEST

Children learn where to look for carbon dioxide and how to test for its presence.

Introducing the Concept

Place the chemical formula for carbon dioxide on the chalkboard. Where have you encountered CO_2 before? What do we know about CO_2? Children may recall that, in Unit One (pages 40, 42), bubbles of carbon dioxide were given off by limestone or marble chips when vinegar was dropped on them. Others, from earlier experiences, may recall that plants use carbon dioxide, that animals breathe it out, that it is a product of burning, or that it bubbles up in soda pop. Seed the idea of its importance, which will be the subject of Section 6, by asking: What if there were no CO_2? Leave the question open; you will keep coming back to it.

Equipment and Materials

See text page 69; also the Teacher's Manual for *Classroom Laboratory 5*.

What is CO_2 like? What are some of its properties? (No color, no odor, a gas.) **How can we get some CO_2?** (Text page 69.) **How do we know when we have it?**

Children should be able to suggest chemical testing. Invite them to learn how by reading the text and planning with you for the investigation on text page 69. Perhaps they may suggest their own design for the investigation.

Children experience some techniques a chemist uses in identifying unknown substances.

Equipment and Materials

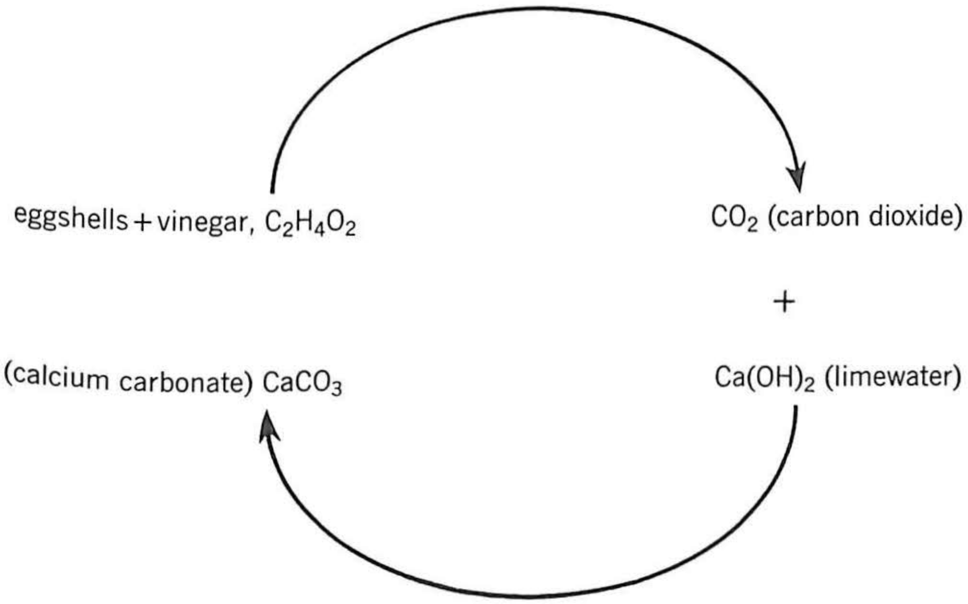
. . . tumbler
. . . paper toweling
. . . milk carton
. . . nail or ice pick

Developing the Concept

From eggshells to limestone. As children carry on the investigation, encourage them to test their observations with these questions. Does litmus paper show limewater to be an acid or a base? (Base.) Is the milky limewater acid or base? (Neither.) What are the white specks in the limewater? The chemist's term is *precipitate,* a solid formed by a chemical reaction.

To determine that a white solid has been formed, let children make a filter by punching holes in the bottom of the carton with a nail or ice pick. Place a folded square of paper toweling snugly over the holes. Pour in a tumblerful of the milky liquid and allow time for it to filter through. Have we separated CO_2 from limewater? (No; CO_2 is a gas; the liquid filtered out tests neutral.) What are some properties of the substance? (White, solid, insoluble in water, tests neutral.) What is it?

Write the chemical symbols for carbon dioxide and limewater, $Ca(OH)_2$, on the chalkboard. Challenge children with the question: What atoms must be in the solid? (Ca, C, O.) Chemists, to identify unknown substances, review properties and set down chemical symbols and formulas to describe chemical reactions. Can you guess what the unknown white substance is? Some children may arrive at the inference that it is calcium carbonate, $CaCO_3$, also known as limestone. It is now useful to write this much of the reaction on the board:


eggshells + vinegar, $C_2H_4O_2$
CO_2 (carbon dioxide)
+
(calcium carbonate) $CaCO_3$
$Ca(OH)_2$ (limewater)

What are eggshells made of? Can they be made of calcium carbonate? How can we find out? You have already used eggshells and vinegar to get carbon dioxide. What will you get by mixing vinegar and calcium carbonate? Children now test their prediction by carrying out the investigation on text page 71. How would you show the complete cycle of carbon-dioxide formation? (Add a + between $CaCO_3$ and $C_2H_4O_2$.)

Extending the Concept

Carbon and calcium in living things. Where are eggshells made? (Inside a bird.) What animals in the sea make shells? (Clams, oysters, other marine organisms.) What happens if a farmer doesn't add bits of seashells to his hens' diet? (Eggshells may become too thin; they contain too little calcium carbonate.) Can you guess why the farmer doesn't feed eggshells back to the hens? (It could give hens a taste for their own eggs.) Do you find calcium carbonate in any animal parts except shells? (Yes, in bones.) How could you use what we have just learned to prove it? (Vinegar applied to a bone should release CO_2.)

To a thoroughly cleaned or, better, to a weathered calcified fragment of bone add vinegar. You can hear CO_2 fizzing (hissing) if you can't see it. Using concentrated or heated vinegar speeds the reaction. This activity may lead children to predict a test for CO_2 in sea and land shells (snails, for example). Testing shells may lead to testing rocks beyond that done in Unit One. A builders' supply yard can often let you have fragments of a variety of rocks. Chalk (real), coral, limestone, travertine, and marble are rocks composed largely of calcium carbonate. Even if the school is not in limestone country, the children can enjoy checking rock samples. Can you think of reasons why calcium carbonate is the most abundant mineral in the earth's crust? (Abundance of oxygen and CO_2.) How could this mineral have gotten into these rocks? (From remains of past life on earth caught in sediment; they have formed deposits of calcium carbonate.)

(*Text pages 72–73*)

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. a

Using What You Know. Carbon dioxide must have been in the soda water; CO_2 plus calcium hydroxide yields calcium carbonate.

(*Text pages 73–76*)

SUBCONCEPT

The production of carbon dioxide is evidence of oxidation within living things.

Processes emphasized

Investigation (and design)
Observation
Hypothesizing
Theorizing
Predicting
Reporting
Model building

Section 6: A COMPOUND LIVING THINGS PRODUCE

Through inferences, hypotheses, and investigation, children start to build the concept that all living things produce carbon dioxide.

Introducing the Concept

Although children may have done this before, let several volunteers demonstrate how blowing through a straw into limewater turns it milky. What evidence does this show? (Exhaled air contains carbon dioxide.) Does the air you inhale have much carbon dioxide in it? How do you know? (Fresh air does not quickly turn limewater milky.) Actually, limewater should not be left exposed to air, as carbon dioxide in the air (about one-fortieth of 1 percent of air) will eventually combine with the limewater and form a thin crust of calcium carbonate. Exhaled air is about 4 percent carbon dioxide.

Do all living things produce carbon dioxide? Do seeds? Is an apple alive? Is yeast alive?

Children investigate oxidation in several examples of living things.

Developing the Concept

What does it mean to be alive? Children *know* they are very much alive. They feel alive, and furthermore they have chemically tested the fact with limewater. But scientists don't jump to conclusions. They make many tests. Here is an apple. Can you prove it is alive? Does it give off carbon dioxide? Invite a brief discussion but leave the question unanswered for the moment. Instead, perform the investigation on text page 75. If moist cotton is omitted, the production of CO_2 from moistened bean seeds is evidence that the beans and not the cotton produced the CO_2. Perhaps the children will infer that seeds are living things able to oxidize carbon to produce CO_2. Where did the carbon come from? (It must have come from food stored in the seed.)

You now come back to the unanswered question: How can you test whether or not the apple gives off carbon dioxide? Hang the apple in one plastic bag, limewater in another. Connect the bags with a length of rubber (or plastic) tubing and seal each bag around the tube with a rubber band. Oxygen in the bag with the apple will oxidize the sugars (carbohydrate) in the apple, and the CO_2 will produce a milky precipitate in the limewater—the CO_2 test. Apples have been found to produce so much CO_2 that a large quantity of apples in an enclosed space could be suffocating.

Do other living things produce carbon dioxide? Another way of generating CO_2 will remind you of bread making. Crumble a fresh cake or package of yeast into ⅓ cup of lukewarm water. Add 1 to 2 teaspoonfuls of sugar. Wrap in flannel or toweling to retain heat. You may wish to tell the children that yeast is a living plant; its cells are alive. Will the yeast produce CO_2? Let the children hypothesize from what they have learned in the lesson and encourage them to wait patiently for about an hour. Then, depending on the surrounding temperature, they will see bubbles of CO_2 rising. As yeast cells grow, they take apart sugar molecules and produce CO_2 and alcohol. Remember that CO_2 is odorless. The characteristic smell of rising bread is that of certain types of alcohols. Let the children suggest ways of collecting and testing the CO_2 being generated as the yeast cells oxidize the sugar.

Extending the Concept

How is limewater made? You may wish to give the children the background for the formation of a limewater solution. If you can locate a good-sized (3–4 lb.) piece of high-grade limestone, break off a third of it for a *control*. What is limestone? ($CaCO_3$.) If the school has a coal furnace, ask permission to lay the large piece of limestone on the fire overnight. Next day, after you have carefully removed it, compare it with the control. The piece from the furnace should have the appearance and friability of chalk. What may have happened? (CO_2 was driven off, leaving CaO, calcium oxide.) The white parts of the limestone have been chemically changed. How could you prove that CaO is left? (Add to water and test with litmus paper for basic reaction; also test control in water.) How else can we prove it? (Bubble CO_2 through a solution of CaO and water and note the formation of $CaCO_3$, the white precipitate.)

Equipment and Materials

See text page 75; also the Teacher's Manual for *Classroom Laboratory 5.*

Children examine the making of carbon dioxide by yeast, and infer that yeast cells are alive.

Equipment and Materials

. . . cake or package of fresh yeast
. . . sugar
. . . teaspoon
. . . toweling

Equipment and Materials

... sugar cube
... tongs
... saucer
... ashes
... glass jar
... limewater

Can a food substance produce CO_2 outside a living thing? What is sugar? (The product of a green plant.) Can we oxidize sugar? Hold a sugar cube in kitchen tongs over a saucer or pan, and apply a match or candle flame. The cube is blackened with soot, but it does not burn. Sprinkle some ashes on a clean cube. (This raises the kindling temperature of the sugar.) When the cube begins to burn, cover it with a glass tumbler or small jar. Watch for formation of water molecules on the inside. How could you test for CO_2? Right the glass and quickly add ¼ inch of limewater. Cover the glass and shake. If enough CO_2 molecules were caught, the limewater should become milky. Where must the carbon have come from to make the CO_2? (From the sugar, produced by living plant.)

The carbon-oxygen cycle. In all their tests thus far, the children have seen that living things—or the products of living things—combine the oxygen in the air with carbon when oxidation takes place. Fuel in automobiles (gasoline) and in furnaces and the like (oil and coal) give off CO_2 when the carbon in them combines with oxygen in the air. Why doesn't our atmosphere grow short of oxygen and fill up with carbon dioxide? Scientists have indeed become concerned with this question. Although the children have not yet been introduced to photosynthesis in this grade (see Unit Six), some may recall from earlier work that green plants take CO_2 from the air to make carbohydrates (starches and sugars) and return oxygen to it. Thus plants, up to now, have been able to maintain the balance of oxygen and carbon dioxide in the air through their intake of CO_2 and their output of oxygen as they build carbohydrates. You may wish to postpone much discussion of this question until the children study photosynthesis more fully in Unit Six.

Developing the concept of the carbon-oxygen cycle sometimes creates the misconception that plants use only CO_2. Like animals, they must also use some O_2 as they oxidize the food they make and convert it to starches and more complex sugars in their leaves, stems, roots, or seeds. Plants use for their own growth some of the food they make. For example, the apple could not have produced CO_2 or grown except by oxidation of food. (A carbohydrate on oxidation yields CO_2 and H_2O.)

(*Text page 76*)

Reviewing the Concept

Before You Go On. A. **1.** b **2.** a **3.** b **4.** a

Using What You Know. 1. Oxygen. 2. Exhaled air has too little oxygen in it to support burning; the carbon dioxide in it inhibits lighting of the candle.

(*Text pages 77–83*)

SUBCONCEPT
The Earth's matter is built up of atoms combined in many ways.

Section 7: A CHEMIST'S VIEW OF THE EARTH

Children move further toward an understanding of the Earth's matter as elements, compounds, and mixtures. Its solids, liquids, and gases are built of a relatively small number of atoms.

Introducing the Concept

What kinds of substances are there in this room? What kinds can you see from our classroom windows? (Ask children to report.) The chalkboard headings, SOLIDS, LIQUIDS, GASES, may help pattern the children's thinking. How would a chemist group the substances listed? If children are unable to suggest the groups, place on the board the column headings, ELEMENTS, COMPOUNDS, MIXTURES. Encourage tentative sorting of the first list and liberal use of question marks. Absolute identification is not of consequence at this point. Children will observe that their listing under elements is the shortest. Why? By now children know that elements are the building blocks of the Earth.

What gaseous element is most common in Earth's solid crust; in Earth's ocean of air; in its waters? Why is oxygen so important to living things? What seven elements make up most of Earth's crust?

Children may now read the text up to page 79. They may not understand the use of decimals in the table on page 77. You may wish to use your own system of approximation of a whole number or explain that 3.5 lbs. is $3\frac{5}{10}$ lbs., that 0.02 lb. is $\frac{2}{100}$ lb., a very small amount, and so on, developing the table in terms of fractions. You may also wish to reinforce the point that the elements listed for the Earth's crust and the Earth's waters are not free but combined with other elements. The gases in the air exist as elements for the most part. What important compound exists in air? (Carbon dioxide—0.04%.) It is included in the table with "other gases."

Processes emphasized

Categorizing
Measurement
Investigation
Observation
Library research
Concept forming

Developing the Concept

The combining of oxygen and metals. After their reading of text pages 77–82, children should be grasping the idea that oxygen is such an active element that it combines readily with many other elements to form oxides. For example, let the children recall how they made oxygen and caused iron to rust in the investigation on text pages 60–61. Is iron the only metal that will combine with oxygen (oxidize)? (No.) Can you think of a way to prove it? The surface of the metallic substances listed in the margin should be abraded clean before exposure to oxygen produced in a generator, as on page 61. Commercial metal polishes such as silver, brass, and copper cleansers may be used. How do they restore the original metals? (Sometimes with mild abrasives, but usually by chemical action which removes the oxides; compare the ingredients listed on the containers of most polishes.) Expose each metal to oxygen. Moistening the metals will speed the reaction. Children observe and describe. Children will notice that the aluminum pan and zinc strip oxidize sooner than the copper and silver compounds in the coins.

Elements in everyday life. After children have completed reading the section, ask: What do chemists use to *build* molecules? (Atoms of elements.) What do chemists *break down* to get elements? (Molecules of compounds.) How many natural elements have been identified? (92.)

Oxygen is an active element; it combines readily with many other elements to form many oxygen compounds.

Equipment and Materials

. . . aluminum pan
. . . copper penny
. . . silver coin
. . . zinc strips

Children gain new and deeper understanding of the chemist's 100 building blocks.

How many other elements have been made in the laboratory? (11.) Which of the seven elements common in Earth's crust are included in the "Important Dozen of Elements" described in the text? For which of the twelve can you find everyday examples? (E.g., aluminum pan.)

By now, it should be apparent that atoms of elements sometimes exist separately. Most atoms, as for example H_2, are grouped into molecules. Even a few different kinds of atoms can combine into many different kinds of substances. Which of the following elements could be represented in an exhibit of elements?

carbon, as in charcoal
sulfur, as in egg yolk
oxygen, as in hydrogen peroxide
nitrogen, as in fertilizer
copper, as in wire
silver, as in coins
gold, as in gilt

Extending the Concept

How fast do different metals oxidize? Chemists have studied chemical reactions of metals and metallic compounds and have devised an *activity series* of the metals. This means, very simply, that the metals at the beginning of the following list are more vigorous than those at the end. After presenting this idea and listing in a column the following partial list, ask which metals are likely to combine more easily with oxygen. Which are likely to combine less easily? (The first three metals combine vigorously; those after mercury do not combine directly with oxygen.) How does the activity series explain that only the metals after hydrogen (though not a metal, it behaves like one) may be found free in nature? Why are elements before hydrogen found only in compounds? (They combine readily with oxygen.)

Potassium
Calcium
Sodium
Magnesium
Aluminum
Zinc
Chromium
Iron
Nickel
Tin
Lead
Hydrogen
Copper
Mercury
Silver
Platinum

Process emphasized
Design of own investigation
(with experiment)

How do metals react with an acid? Children can recall that vinegar, a mild acid, is a compound containing hydrogen, $H_2C_4O_2$. What compound would be formed if a zinc strip were to be placed in vinegar? (Zinc oxide.) What gas would be given off? (Hydrogen.) From the activity series, would magnesium react more vigorously than zinc? (Yes.) Would tin? (No.) Will silver react with vinegar and release hydrogen? (No. Silver is below hydrogen in the activity series.) The rate at which hydrogen is given off from an acid provides an index of the chemical activity of metals.

Shine some coins with steel wool. Place them in solutions of such substances as vinegar, powdered sulfur, soda pop. What will happen?

Here is an opportunity for open-ended investigation with a variety of household chemicals. Dilute as recommended on the containers.

Reviewing the Concept

(*Text pages 82–83*)

Before You Go On. A. 1. a 2. a 3. a 4. b

Using What You Know. 1. Nitrogen. 2. Sodium chloride. 3. Oxygen combines readily with hydrogen, many metals, and a few other elements such as carbon and sulfur. 4. Oxygen, silicon, aluminum, iron, calcium, sodium, potassium.

On Your Own. Measure the weight or volume of the minerals left in the pan.

Section 8: MORE WEIGHT OR LESS?

(*Text pages 83–85*)

SUBCONCEPT

In oxidation, matter is neither gained nor lost.

Children begin to realize that when substances oxidize there is no gain or loss of matter; the original substance may change in form or state.

Introducing the Concept

Equipment and Materials

. . . quart milk cartons

In advance of the class meeting, partially fill a pair of quart milk cartons with water until each weighs the same. Seal both and place one in the refrigerator. Explain to the children as you show the cartons. Will the weight of the cartons be the same or different? Weighing on scales will verify or disprove the children's prediction.

In a physical change the amount of matter remains the same. What about a chemical change?

Developing the Concept

Children infer there is no change in weight as atoms recombine into new substances.

Equipment and Materials

. . . rusted juice can
. . . unrusted juice can
. . . steel wool

Does the total weight change when iron combines with oxygen? Hold up two identical juice cans, one rusted and one unrusted. Of what elements is the unrusted can made? (Probably iron with a zinc or tin plating.) Of what elements is the rusted can made? (The same, but with some of the plating worn off, plus oxygen in the rust.) Which can weighs less? (Of course the rusted can weighs less.) Here is a puzzle. It would seem that the rusted can should gain weight since oxygen has been added to the elements of the can. But it weighs less. Has matter been lost by the can? Has matter been gained, since we have iron oxide on one can but not on the other? How can we find out? After recording the children's educated guesses, encourage them to set up the investigation with you as they read the text of the section. Incidentally, a slender strip of wood doweling supported at midpoint can be used as a balance.

Now let's reason together. Can any matter get in or out of the closed jar? Has the jar with the air plus the steel wool gained or lost weight? (Neither.) Has any matter been gained? Lost? What has happened? Atoms in the molecules of iron and oxygen have recombined to form iron oxide. There is less iron and oxygen in the jar and more iron oxide. No matter has been gained or lost; there is only a new substance. Can you now reason out why the tin cans did not weigh the same? HINT: How did we make certain nothing else got into the jar? (We capped it tightly.)

No atoms are gained or lost in a chemical change.

Processes emphasized

Investigation (and design)
Hypothesizing
Theorizing
Predicting
Measurement
Reporting
Analysis of data

Is the total of the products of combustion different from the total of the substances in the reaction? The elements in a candle are chiefly carbon and hydrogen. When a candle burns, is matter lost? (No.) What happens to it? (Oxygen in the air combines to form water vapor and carbon dioxide.) How is it that a grown man may have to carry in the log for a fireplace, but a child can carry out the ashes? Has matter been lost? (No; oxygen from the air has combined with the substances, chiefly hydrogen and carbon, in the log to form carbon dioxide and water vapor.) Why does there seem to be a loss in weight? (Water vapor and carbon dioxide have escaped; the log was not burned in a closed container.)

Extending the Concept

Reasoning it out. You may wish to settle for the conclusions and assumptions above, but with a good class you may wish to go further. Chemists, after numerous experiments, know that the following chemical equation represents one way iron and oxygen combine to form an iron oxide compound:

$$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$$

Compare the equation to a yardstick (or dowel) balance. On the right side are 2 molecules of iron oxide with 4 iron atoms (or any weight or volume unit) and 6 oxygen atoms in the compound. On the other side are 4 iron molecules (4 atoms) and 3 oxygen molecules (6 atoms). The 10 atoms on each side of the arrow just balance each other. Elements in a compound always combine in the same quantities. This is known as the Law of Definite Proportion, a concept beyond most children at this grade level, but they may understand that elements combine in fixed amounts. The amounts that combine always just balance the amounts that result from the combination. That is, the equation shows that matter is neither gained nor lost in a chemical reaction.

Recalling what has been learned. Recall in review related learnings and activities from Section 3, beginning on page 60. When mercury and oxygen combine to form mercuric oxide, is any more matter gained? Is any matter lost? What happens when copper and oxygen combine? Will there be any gain or loss of matter when *any* oxide is formed? You may wish to relate to the children Antoine Lavoisier's famous experiment of burning mercury and oxygen in a closed container. Until he performed this and similar experiments repeatedly, less than 200 years ago, everyone thought that substances gained weight when they were burned (oxidized).

(*Text page* 85)

Reviewing the Concept

Before You Go On. No matter is gained or lost; if two elements combine to produce a compound, the weight of the compound is equal to the combined weights of the elements in the chemical reaction. Any oxide is an example.

Using What You Know. 1. 88 lbs. 2. 56 lbs.

Section 9: THE MAIN CONCEPT: THE EARTH'S BUILDING BLOCKS

(Text pages 86–89)

Children strengthen their growing understanding that the amount of matter resulting from a chemical reaction is neither more nor less than the amounts of the substances that took part in the reaction.

CONCEPTUAL SCHEME

When matter changes from one form to another, the total amount of matter remains unchanged.

CONCEPT SUMMARY

UNIT CONCEPT

In chemical and physical change, the total amount of matter remains unchanged.

After children have read the section, there are several ways of bringing together around the central concept of the unit the work they have done. For example, you have seen that the chemist arranges and rearranges atoms in molecules of elements and compounds to form new substances. Sometimes he breaks down molecules; at other times he builds up molecules. All the matter of the Earth is made of atoms of elements. How many of the building blocks are there? (103.) How does a chemist know what he is doing? (He studies properties, he makes chemical tests, he learns how atoms and molecules combine.)

What are the properties of some common elements and compounds?

What are some of the properties of metals? (Color, luster, solids except for mercury; most combine more or less readily with oxygen to form oxides.) What makes them different from the substances that formed them? (Oxygen is a gas, metallic oxides are solids, usually soft and brittle and dull in color compared with the metals.) What are two of the most common oxygen compounds? (Water and carbon dioxide.) What are some of their properties? (Water—a liquid, dissolves many solids; carbon dioxide—a colorless, odorless gas.)

What are some chemical tests we use?

What are some chemical tests you have used in this unit? (Litmus paper, limewater, calcium carbonate.) How do you test for an acid? (Blue litmus turns pink.) A base? (Pink litmus turns blue.) Carbon dioxide? (It forms a flaky, white oxide when bubbled through limewater.)

How can we classify substances?

How do properties and chemical tests help the chemist classify substances? (Each substance has its own properties; it reacts in the same way to the same test.) What are some common groups of substances? (Oxides; acids, bases, salts; solids, liquids, gases; elements, compounds.)

What unit of matter does the chemist work with? (Atom.) Of what unit are compounds composed? (Molecules.) What is the difference between an atom and a molecule?

FIXING THE MAIN CONCEPTS

(Text pages 87–89)

A. **1.** Larger; molecules are larger than atoms. **2.** Bases. **3.** 1 lb. **4.** More; weight of oxygen is added to weight of mercury; the amount of matter in a compound must equal the weight of the substances used to make it.

B. Complete sentences should contain ideas as developed in the unit and defined in the glossary of the child's text.

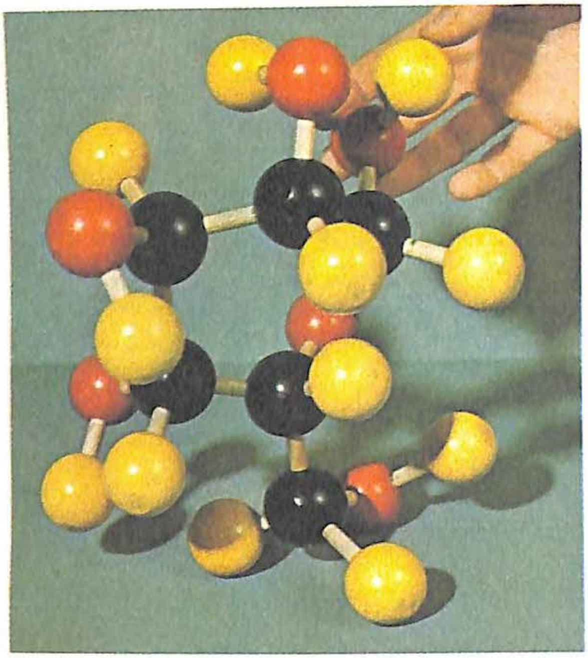
C. **1.** d **2.** c **3.** b **4.** d **5.** c

UNIT TWO

ABOUT 100 BUILDING BLOCKS

Blow into the air. Can you see your breath? Blow against a mirror. A thin film forms on the mirror—a film of water. Here is evidence that you blow water out of your lungs. Yet you cannot see the water as it comes out. It is invisible, because the particles of water that you blow out are so small. These particles are molecules, and you cannot see a molecule of water. However, the mirror catches enough molecules to make small drops. Each drop has billions of molecules in it.

How does it happen that we believe in something we can't see, that we believe in molecules? What makes scientists think that there are molecules all around us, and that we ourselves are made up of molecules? Scientists have gathered evidence for many years about molecules, and have reasoned from the evidence. Let's look at some of this evidence, and some of the reasoning of scientists who have studied these building blocks of matter.



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1. Molecules

What is a molecule?

If you wet a finger, put it in the sugar bowl, and then put it in your mouth, you expect a certain taste. Sugar has a certain taste. Scientists say that this certain taste is a **property** of sugar.

Take another example. Ammonia has a certain odor, which you probably know. That odor is a property of ammonia.

Water is colorless. In other words, a property of water is that it has no color. (It has other properties as well, of course.)

Have you ever used salt when you meant to use sugar? You knew at once, by its properties, which was salt and which was sugar! Different substances, like salt and sugar, have different properties. We recognize a substance by its properties, don't we? The properties of a substance help to tell us what the substance is.

Now we can give an answer to the question: What is a molecule? **A molecule is the smallest particle of a substance that still has the properties of that substance.** Let's see what this means. Collect some evidence yourself that the properties of a substance go with these tiny particles. Try the investigation on the opposite page.

What Are Molecules Made Of?

The smallest part of a substance that is still that substance is a molecule. The smallest part of perfume that is still perfume is a molecule of perfume. The smallest part of sugar which still has the properties of sugar is a molecule of sugar.

Suppose you take some sugar and heat it in a test tube. The sugar becomes black. And on the side of the test tube, drops of liquid appear. The black substance is carbon. The drops are water. So perhaps the sugar is made up of different substances.

Chemists, the scientists who study changes in matter, have looked into what molecules of sugar are made up of. A molecule of sugar is made up of even smaller particles, called atoms.

Here is a model of a molecule of a sugar named glucose. ■ It is made

AN INVESTIGATION into Properties of a Molecule

Needed: a balloon, a jar with a wide mouth, a funnel, and perfume

First, smell the air in the jar to be sure that there is no perfume in it. Now, using the funnel, place a few drops of perfume in the balloon. See the picture marked with a square. ■

Blow up the balloon, and firmly tie a knot in its neck so that no air can escape. ● Fit the balloon tightly into the mouth of the jar. ▲

Let the balloon stay in the jar for 15 or 20 minutes. Then carefully take the balloon out of the jar. Smell the air in the jar.

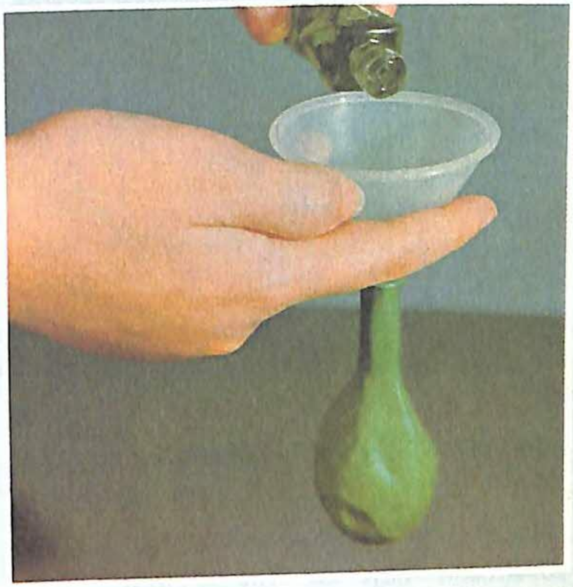
What do you smell?

How could perfume get into the air in the jar from inside the balloon?

Let's look at the evidence. The air in the balloon had perfume in it. The perfume must have passed through the rubber of the balloon.

How can this happen? It happens because the particles of perfume are so tiny that they can pass through the rubber. Indeed, these tiny particles are molecules. And these molecules carry with them the properties of the perfume. So you are able to smell perfume in the air of the jar.

Additional Investigation: Can molecules of the gases in air go through a balloon? Set up an investigation of your own to answer this question.



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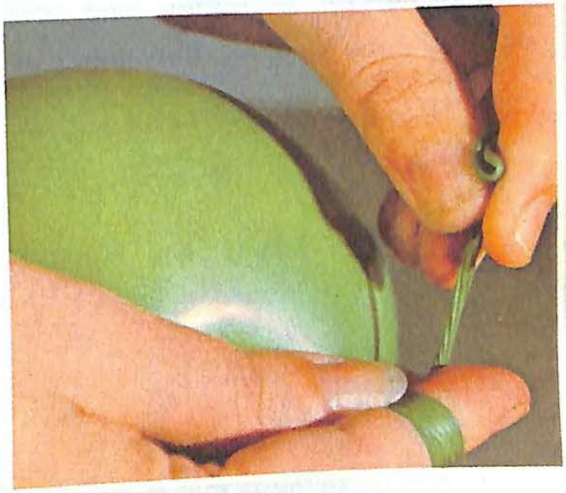

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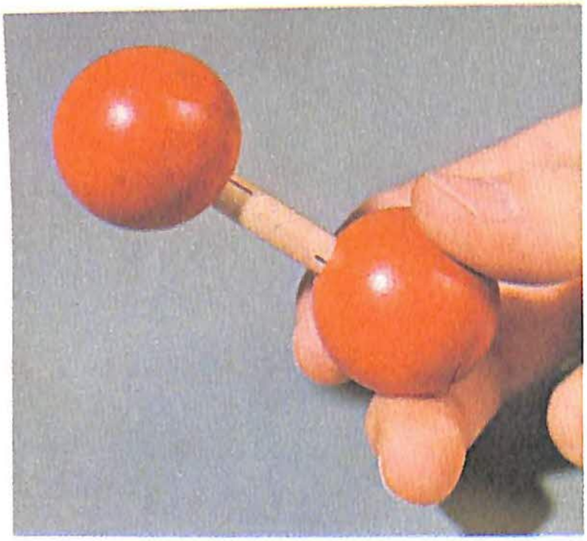

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up of six atoms of carbon (black), twelve atoms of hydrogen (yellow), and six atoms of oxygen (red). This molecule can be taken apart into atoms of carbon, hydrogen, and oxygen. But none of the atoms has the properties of sugar. The molecule of sugar is the smallest part of the substance sugar.

What about a substance like oxygen? Oxygen is made up of only *one* kind of atom. So oxygen is called an **element.** An element is made up of only one kind of atom. Oxygen atoms travel in pairs. It takes *two* oxygen atoms to have the properties of oxygen. So *two* oxygen atoms make up a molecule of oxygen. ■ The molecule of oxygen is the smallest part that has the properties of oxygen.

Molecules may be made of different kinds of atoms, or one kind of atom. But all molecules are made of atoms. And all substances are made up of one or more atoms.

BEFORE YOU GO ON Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Different substances, such as sugar and salt, have properties that are

a. the same b. different

2. The smallest particle of a substance, such as sugar, that still has the properties of that substance is called

a. a molecule b. an atom

3. Molecules are made up of

a. properties b. atoms

4. Which one of these is an element:

a. sugar b. oxygen

USING WHAT YOU KNOW

1. These substances are elements:

nitrogen hydrogen

These substances are not elements:

sugar starch

a. Which of these substances are made up of only one kind of atom?
b. Which of these substances are made up of different kinds of atoms?

2. All molecules are made up of atoms. Which do you think are smaller, atoms or molecules? What makes you think so?

ON YOUR OWN

1. Silver, gold, copper, and iron are all elements. Each of these elements is made up of only one kind of atom. Is a silver dime, a gold ring, a copper penny, or an iron nail each made of one kind of atom?

2. As a mercury thermometer gets warmer, the mercury expands. What happens when mercury expands? Mercury is an element. Do more molecules of mercury appear? Or does the space between molecules get larger?

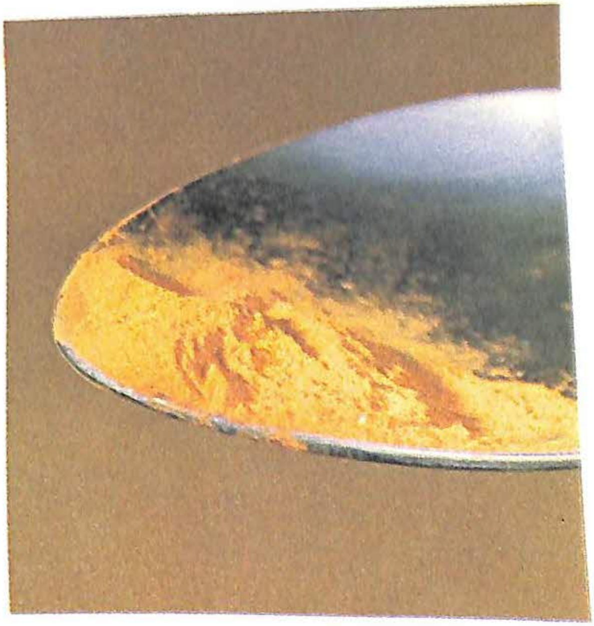
2. Breaking Down a Molecule

Let's break down a molecule.

Of course we can't handle just one molecule. But we can handle a bunch of molecules of one substance.

Let's take a molecule that is made up of two different atoms, and can be broken down right in the classroom. We shall take some molecules of the substance called **mercuric oxide** (mər-kyo͝or′ik ok′sīd).

Mercuric oxide is an orange-red powder. ● Mercuric oxide is made up



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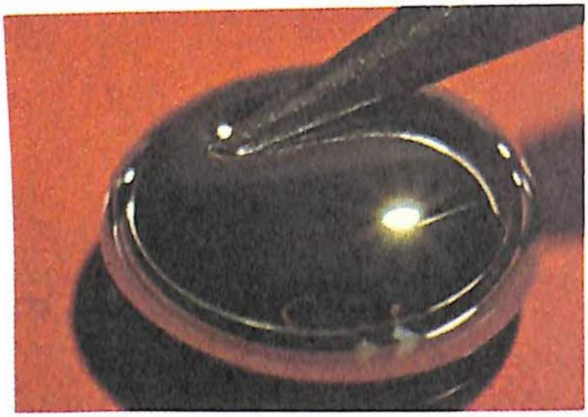

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of atoms of mercury and of oxygen. These are two very different elements, not at all like red powder. The atoms of the element mercury form a heavy, silvery liquid. ■ Oxygen is a colorless, invisible gas. Can a silvery liquid, mercury, and an invisible gas, oxygen, combine to make a red powder? Let us break down molecules of the red powder, mercuric oxide. If we can get mercury and oxygen out of the mercuric oxide, then we will know that these elements went together to form mercuric oxide. See for yourself by doing the investigation on the opposite page.

Getting the Elements

As the red powder of mercuric oxide is heated, it turns black. Drops of mercury begin to appear. Oxygen is being given off too, but passes into the air. It is a colorless gas, without an odor, so you don't see it, or smell it. Only mercury is left. The red powder is made of a silvery liquid and an invisible gas, mercury and oxygen.

Mercury is an element. It is made up only of atoms of mercury. Oxygen is an element made up of molecules of oxygen. The elements mercury and oxygen can combine to form a new substance, mercuric oxide. ● Chemists call this new substance a **compound.** A compound is formed when two (or more) elements are combined. Mercuric oxide is a compound of the elements mercury and oxygen. No other atoms are part of this compound.

Look at this compound another way. Mercuric oxide is made up of molecules. Each molecule of mercuric oxide is made up of two different kinds of atoms, atoms of mercury and atoms of oxygen. Heating mercuric oxide makes the molecule break apart.

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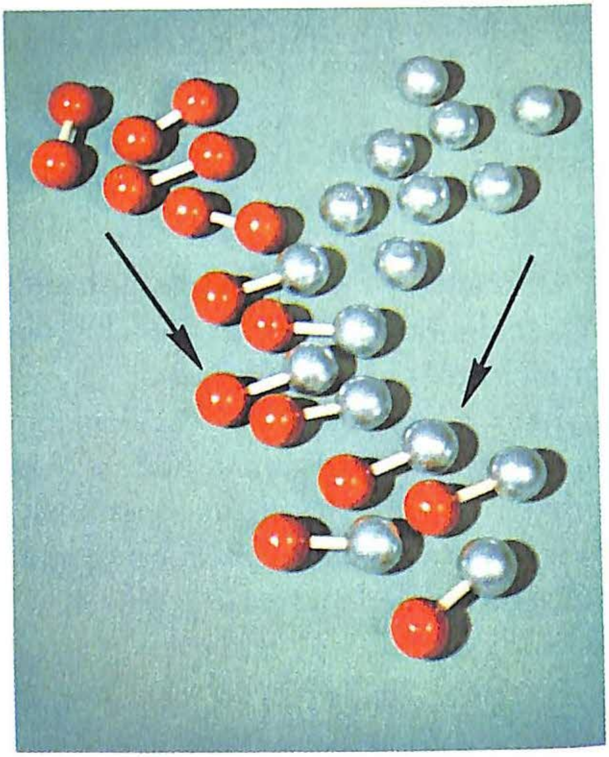


AN INVESTIGATION into Breaking Down a Molecule

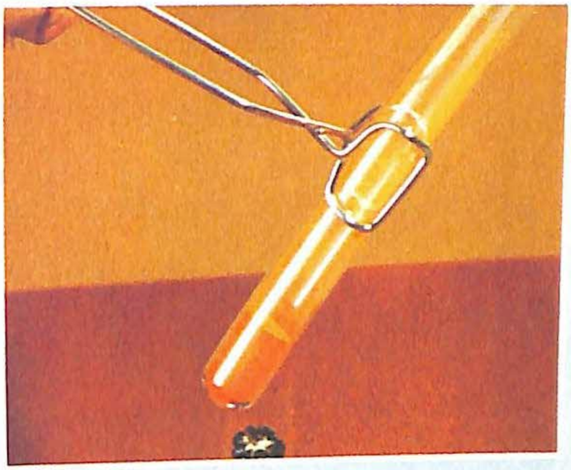
Needed: a Pyrex test tube, a test-tube holder, an alcohol lamp or Bunsen burner, a saucer, and a little mercuric oxide powder

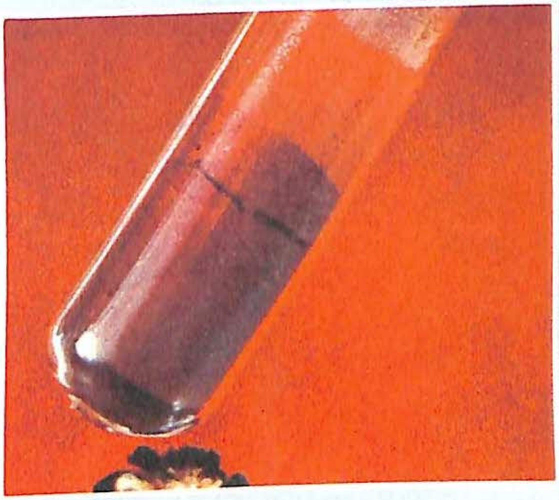
Pour some mercuric oxide powder into the Pyrex test tube. Be careful not to touch the powder with your fingers, and be careful not to breathe in any of it. Clamp the test-tube holder around the top of the tube and heat the mercuric oxide. **Keep the test tube tilted away from you as it is being heated.** ■ **Be sure that it is never pointed at anyone. Don't breathe in the fumes.**

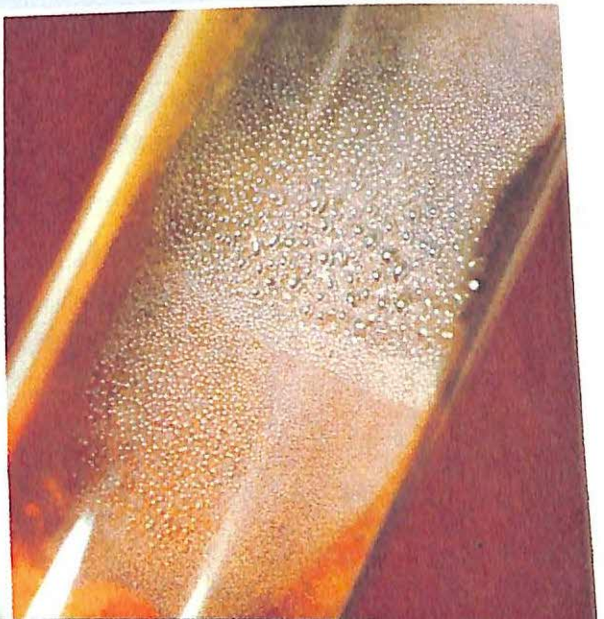
Observe what happens as the red powder is heated. The mercuric oxide begins to turn black. ● Then silvery drops form on the inside of the test tube. ▲

The silvery drops are mercury. As soon as some mercury has formed, put the tube down on the saucer to cool. **Do not touch the test tube—it is very hot. Never touch a heated tube.** When the tube has cooled, wrap it in paper and ask your teacher what to do with it. It should not be left around.

Additional Investigation: What happens to the powder as it cools again? Can you explain this?







3. Building Up a Molecule

We have seen how a compound can be broken down. We have seen how the molecule of mercuric oxide can be broken down into atoms of mercury and oxygen. Now let's see how a compound can be built up from atoms. We shall build up a compound called iron oxide. Perhaps you know iron oxide as rust.

To build up the compound iron oxide, we need two common elements —iron and oxygen.

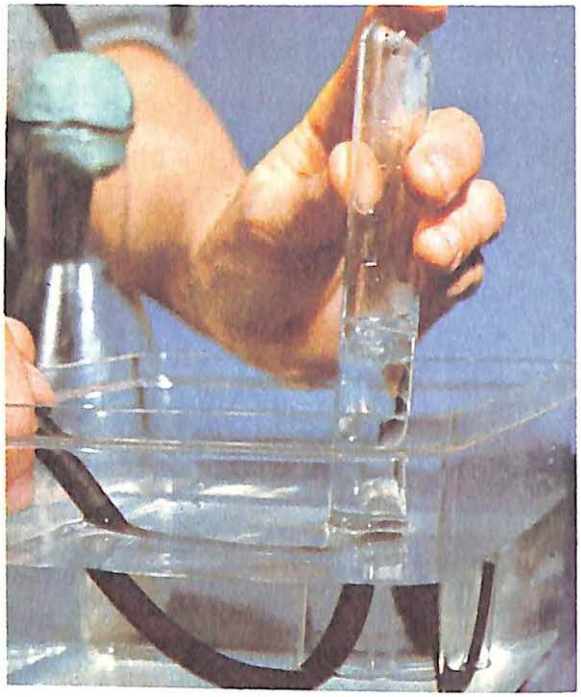
For iron we can use steel wool and a nail. A nail isn't pure iron—it is made of steel, like steel wool. But steel is made up mainly of iron. The iron in the steel wool and nail will do for our purpose.

Oxygen is needed. Of course we could use the oxygen in the air. But only about $\frac{1}{5}$ of the air is oxygen. We can get more oxygen to act on the iron. We can use a compound which gives off oxygen. The compound is called hydrogen peroxide. Try it for yourself, in the investigation beginning in the next column.

Making a Compound

In a few days a moist nail or steel wool exposed to oxygen changes. It takes on a red-brown coating of rust. Chemists call rust iron oxide, because it is a compound of the elements iron and oxygen. When oxygen acts on

AN INVESTIGATION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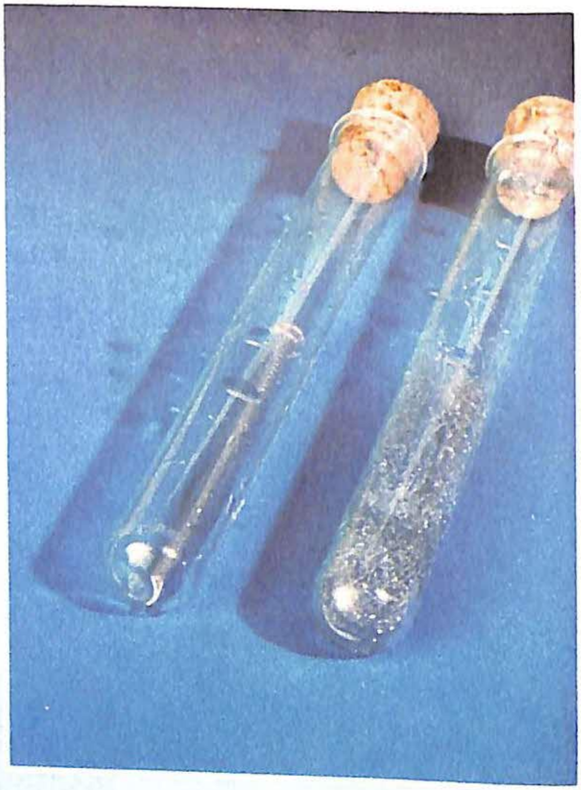
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into Preparing Oxygen and Making Rust

Needed: a bottle of 3-percent hydrogen peroxide (obtainable in a drugstore), a package of powdered yeast, about $1\frac{1}{2}$ feet of plastic or rubber tubing, two test tubes with corks to fit, a pan, a small flask, a piece of modeling clay, an iron nail, some plain steel wool (not a scouring pad)

First, make a gas generator to produce oxygen. Mold a ball of clay around the tubing, about an inch from one end, big enough to plug the neck of the flask. Don't plug the flask yet.

Fill the pan half full of water. Fill a test tube to the top with water. Put your thumb over the mouth of the test tube, turn the test tube upside down, and stand it in the pan. When you take your thumb away, the water will remain in the test tube. Do the same with the other test tube.

▲

Pour 3-percent hydrogen peroxide into the flask until it is about half full. Pour in the yeast powder. Quickly plug the flask tightly by putting in the clay ball and tubing. Make sure the tubing does not touch the liquid. Place the other end of the tubing under water in the pan. The tubing is called the delivery tube because it delivers the gas.

Bubbles will begin to come from the delivery tube in a few seconds. The first bubbles will be air that was in the flask and tube. Soon oxygen will bubble from the delivery tube. Put the tube under the mouth of one test tube, under water. ■ The oxygen from the delivery tube will move the water out of the test tube, and leave it full of gas. Fill both tubes with pure oxygen.

Do the next step under water so that no oxygen escapes from the test tubes. Slide the iron nail into one tube of oxygen, under water. Cork the tube. Push the steel wool into the other tube, and cork it, under water. Now the test tubes can be taken out of the pan.

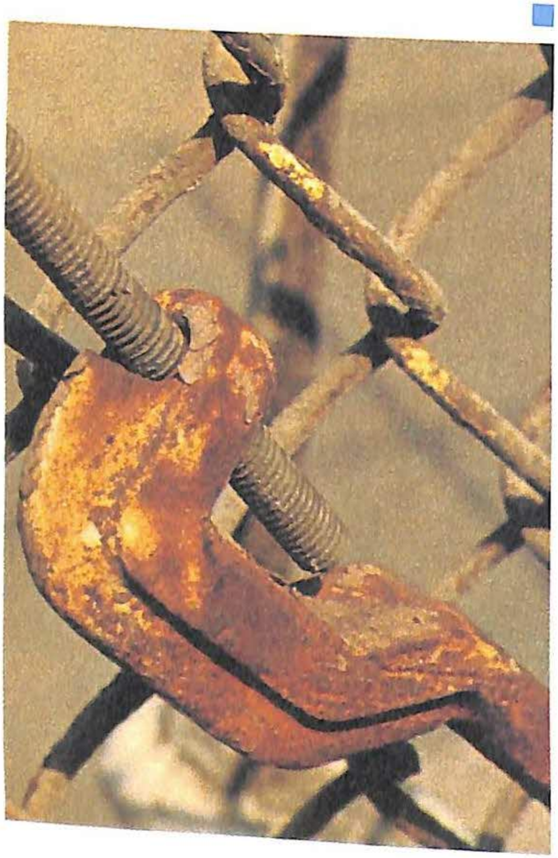
In each test tube there is fairly pure oxygen, and iron. ● Watch what happens during 2 or 3 days.

What have the iron atoms and oxygen atoms combined to form in this trial? ▲

Additional Investigation: Which makes rust more quickly, a nail or steel wool? Does a penny rust? Does aluminum rust? Does copper rust? Why?

iron, atoms of iron and oxygen combine. The result is a new substance, iron oxide, a compound that is unlike either iron or oxygen.

Why is this compound of iron and oxygen important? A bridge can be weakened by rusting, as the iron in steel combines with oxygen in the air. It is easy to see why the steel of a bridge is painted. Paint can help keep oxygen atoms in the air from reaching iron atoms in the bridge and forming iron oxide. The coat of paint on an automobile helps stop rusting. If the coat of paint is broken, however, oxygen can combine with iron to form iron oxide, and perhaps even make a hole in the steel body of the car. Iron combines easily with oxygen. When iron is wet, it combines even more easily with oxygen than when it is dry.



Chemists write this combination of iron with oxygen in this way:

iron + oxygen ⟶ iron oxide

Remember that the arrow stands for "becomes" in the equation.

Do you recall this other compound and its elements?

mercury + oxygen ⟶ mercuric oxide

Notice that one element is the same in both these equations. And notice that the compounds are alike in one thing.

Why is this so?

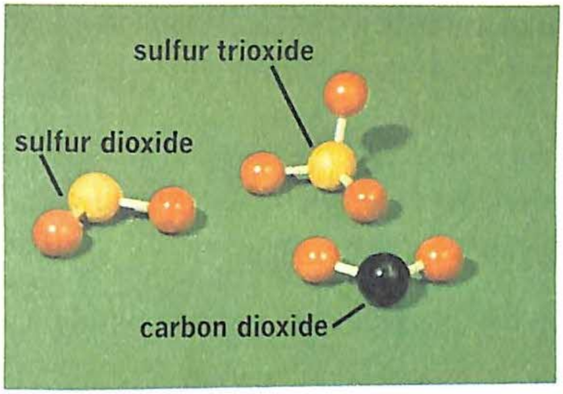
Sorting Out Compounds

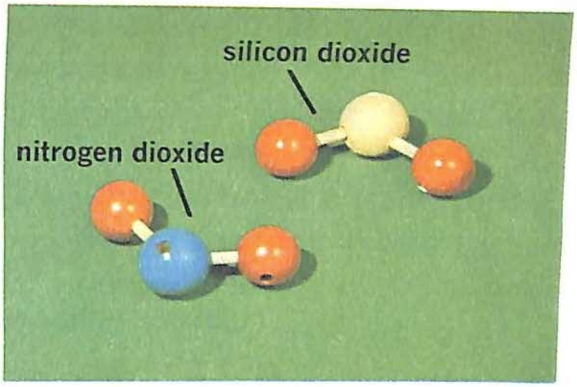
We have seen how mercuric oxide can be broken down into mercury and oxygen. We have seen how iron oxide can be built up from the elements iron and oxygen. What is the one element in these combinations that is the same? You are right if you say "oxygen." Both compounds contain oxygen. And both compounds are called **oxides.** An oxide is a compound of oxygen and another element.

iron + **oxygen** ⟶ iron **oxide**

mercury + **oxygen** ⟶ mercuric **oxide**

We can tell from its name that the compound aluminum oxide is made up





of aluminum combined with oxygen. Water is a compound of hydrogen and oxygen. It would be correct to call water hydrogen oxide. Copper oxide is a compound of copper and oxygen.

There are many other kinds of oxides. In fact there is a whole *group* of compounds called oxides. ● One important task of scientists is to group or **classify** things. We classify matter into solids, liquids, and gases. We classify matter into elements and compounds, too. Now we see that compounds themselves can be grouped or classified as well. One group of compounds is made up of oxides.

See how useful this classifying is. For now, when we hear the word oxide, we know how *any* compound belonging to that group is made up! It has to be a compound of oxygen and another element.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The compound iron oxide is made up of
   a. two kinds of atoms b. three kinds of atoms

2. Whenever we see the word oxide, we know it has to do with a compound containing
   a. hydrogen b. oxygen

3. Iron oxide is a compound containing
   a. oxygen b. rust

4. When they classify substances, scientists
   a. group them b. mix them up

B. Iron, zinc, copper, and mercury are metals. What happens to these metals when they combine with oxygen?

USING WHAT YOU KNOW

1. Here is a word equation for *building up* a compound:

iron + oxygen ⟶ iron oxide

Here is a word equation for *breaking down* a compound:

mercuric oxide ⟶ mercury + oxygen

See if you can write word equations for the *breaking down* of:

iron oxide   water   aluminum oxide

2. Rusting means that iron combines with oxygen. Does rusting take place only when there is moisture? In the investigation on pages 60–61 the nail and steel wool were moistened. Plan an investigation to show whether dryness helps or stops rusting. Show your plan to your teacher. Then try it.

ON YOUR OWN

1. Why are steel cans coated with tin?

2. What does *galvanized* mean? Why are some objects galvanized?

3. Why doesn't stainless steel get rusty?

4. Two Common Groups of Compounds

We have looked at a few compounds belonging to the group called oxides. We have seen how grouping and naming of a compound helps us to know at once what makes it up. Thus the word oxide tells us that the compound has oxygen in it.

Let's look at some other groups of compounds. There are two groups of compounds that are very common, and easy to identify. To find out whether a compound belongs to one of these groups we can give it a **chemical test.** This chemical test is done with strips of special paper called **litmus paper.**

There are two kinds of litmus paper. One is pink, the other is blue. How are they used in a chemical test? Try the investigation on page 66 and find out for yourself. Then come back to this page.

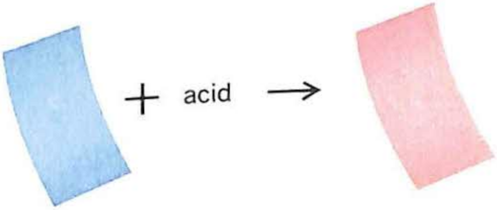
Testing with Litmus Paper

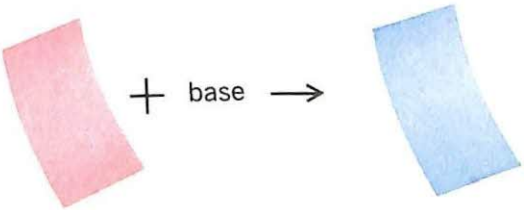
When blue litmus paper is touched with a drop or two of vinegar, the blue color changes to pink. What makes this happen? Vinegar has in it a compound called acetic acid. Acetic acid is one of a whole group of compounds called **acids. Acids turn blue litmus paper to pink.** If acid is touched to pink litmus paper, there is no change in color—the paper stays pink.

However, when pink litmus paper is touched with a drop of household ammonia, the pink paper turns blue. This might make you suspect that household ammonia is different from vinegar. So it is. Household ammonia is a compound called ammonium hydroxide. Ammonium hydroxide is not an acid. It is one of a group called **bases.** Ammonium hydroxide is a base. **Bases turn pink litmus paper blue.**

So litmus paper is a test for two groups of compounds—acids and bases. Acids turn blue litmus pink. Bases turn pink litmus blue. ■ However, some very weak acids and bases won't change litmus paper.

Litmus paper is a chemical test—a chemical test for acids and bases. Put this chemical test to work on some common substances. Try the investigation on page 67.





AN INVESTIGATION into Changing the Color of Litmus Paper

Needed: two strips of blue litmus paper, two strips of pink litmus paper, two medicine droppers, a saucer or dish, vinegar, household ammonia ■

Place the strips of litmus paper in the saucer or dish. Take up a little vinegar in one medicine dropper. Put one or two drops of vinegar on one strip of pink litmus paper. Put a drop or two on a blue strip. Observe what happens. Here is what happened in one trial. ●

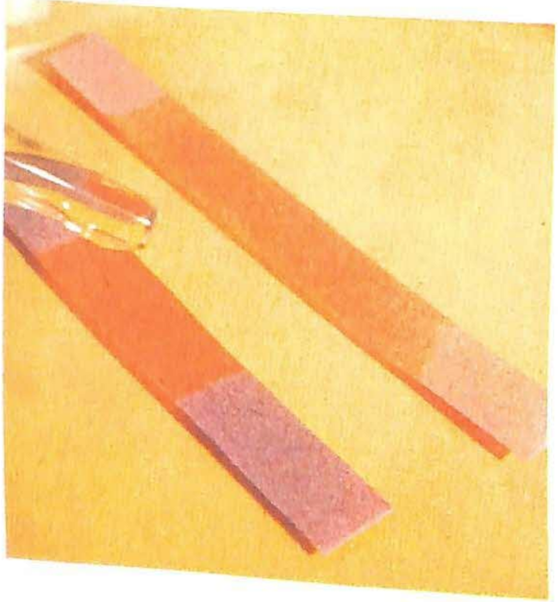
■

Now make the same test with household ammonia. Use the other medicine dropper and the other two strips of litmus paper. Observe what happens when a drop of ammonia is placed on litmus paper. Do not touch ammonia—keep it away from the eyes and mouth. Here is what happened in one trial. ▲

What happened to litmus paper in vinegar?

What happened to litmus paper in ammonia?

Additional Investigation: Can litmus paper be changed back to its first color? Now turn back to page 65.



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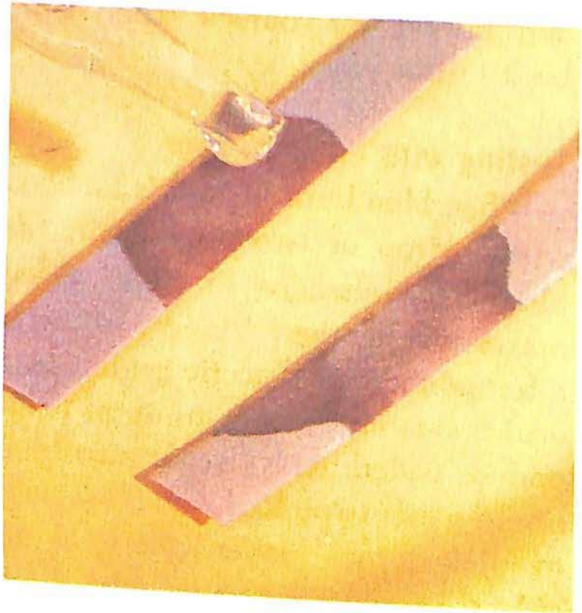

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AN INVESTIGATION into Testing for Acids and Bases

Needed: two small jars (baby-food jars will do), two medicine droppers, three saucers or plates, three pink and three blue litmus paper strips, a lemon, washing soda, and limewater

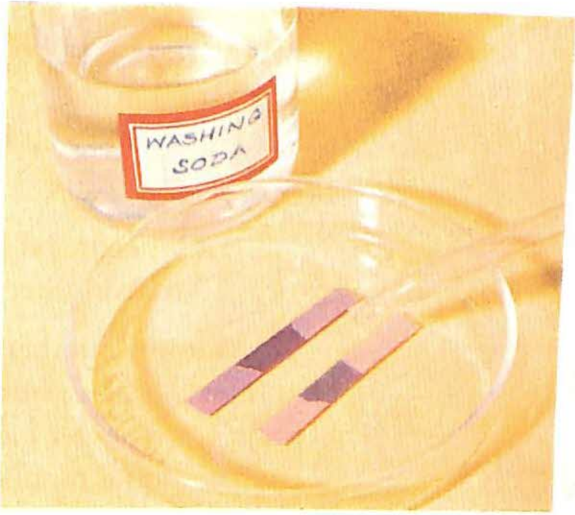
First make a solution of washing soda. Fill a jar about half full of water. Dissolve a level tablespoon of soda in the water. Stirring will make the soda dissolve more quickly.

Pour a little limewater into the other jar. Cut a slice of lemon.

Now, to test these substances, place a blue and a pink litmus strip on one saucer. Put a drop or two of washing soda solution on each of the pink and blue strips. ■ Use the other medicine dropper to put a drop of limewater on the second pair of strips. ● Squeeze a drop of lemon juice on the third pair. ▲ The photographs show what happened in one trial.

Make a record like this of the results.

The substance	Acid or base?
washing soda (sodium carbonate)	
limewater (calcium hydroxide)	
lemon juice	



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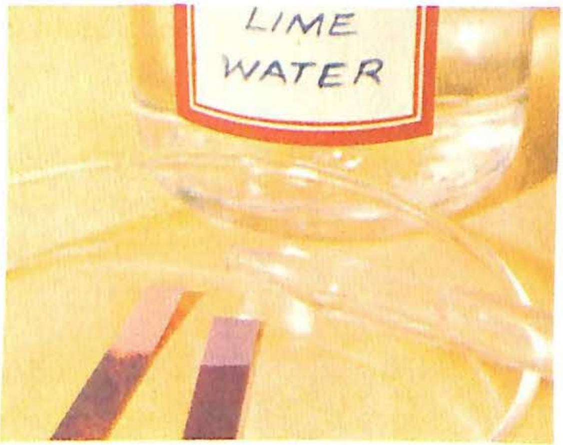

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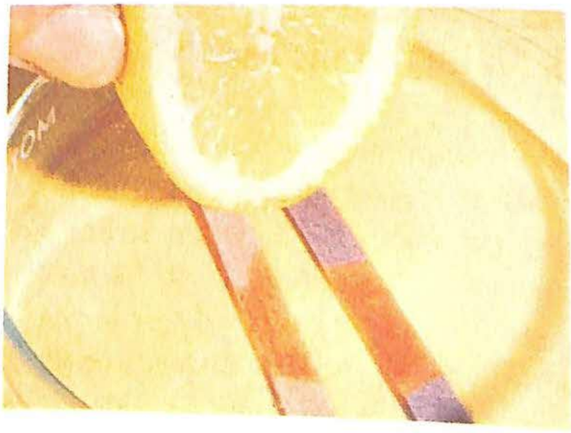


▲

BEFORE YOU GO ON Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Ammonium hydroxide is
   a. an acid b. a base
2. In ammonium hydroxide, pink litmus paper will
   a. turn blue b. remain pink
3. In vinegar, pink litmus paper will
   a. remain pink b. turn blue
4. Liquid number 1 turns pink litmus a light blue. Liquid number 2 turns pink litmus a darker blue. Which one do you think is a stronger base?
   a. liquid number 1 b. liquid number 2
5. Litmus paper is used to make
   a. acids and bases b. a chemical test

USING WHAT YOU KNOW Sodium hydroxide is a common compound. Pink litmus turns blue in a solution of sodium hydroxide. Would you classify sodium hydroxide as acid or base?

ON YOUR OWN The acid found in lemons just barely turns blue litmus pink. What kind of acid is it?

5. An Important Test

A compound we meet again and again is carbon dioxide gas. But how can we recognize it, when it has no color and no odor? As it happens, there is a simple chemical test for carbon dioxide. The test makes use of a liquid called limewater.

Limewater is a clear and colorless liquid. When carbon dioxide gas combines with it, however, limewater turns a cloudy, milky color. Whenever limewater turns milky, we know at once that carbon dioxide is present. To see for yourself how this happens, try the investigation on the opposite page.

AN INVESTIGATION into Testing for Carbon Dioxide

Needed: a gas generator (see page 61), eggshells, vinegar, limewater, two test tubes, and a cork

Put pieces of eggshell into the empty flask until they are about an inch deep.■ Pour in vinegar until the flask is about three-quarters full. Close the flask tightly, making sure that the end of the delivery tube is not touching the vinegar. Put the other end of the delivery tube under water.

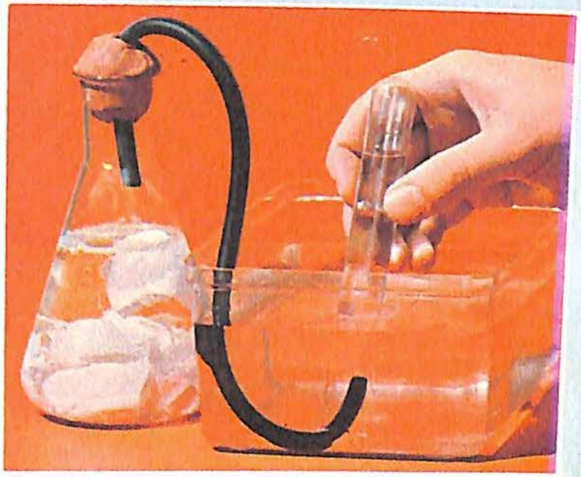
Fill the test tubes with water and place them upside down in the collecting pan.

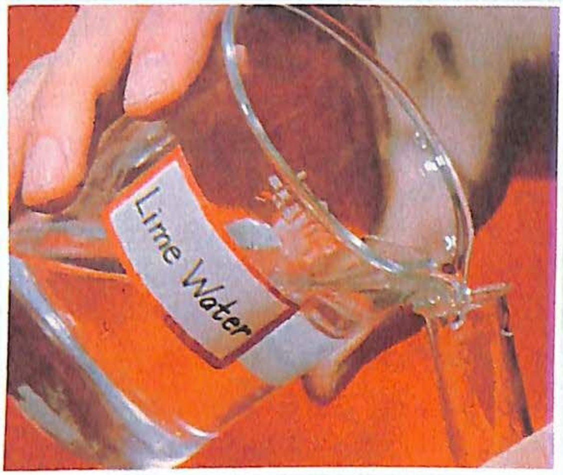
When bubbles begin to come from the end of the delivery tube under water, wait about 10 seconds. Then put the end of the delivery tube under each test tube and collect the gas coming from the generator. This gas is carbon dioxide.

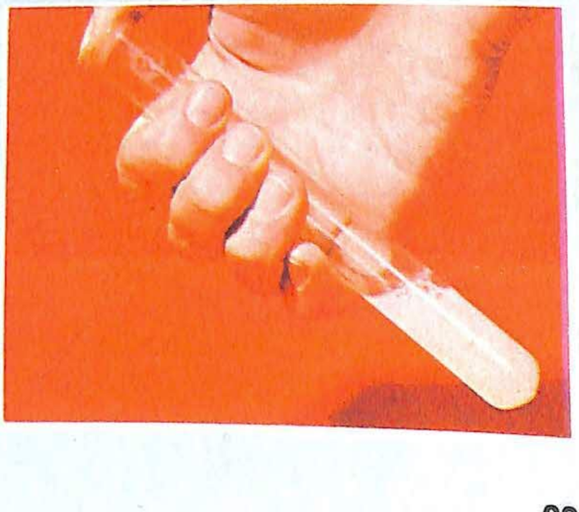
Put your thumb over the mouth of a test tube full of carbon dioxide gas, under water. Remove the tube from the collecting pan. Holding the tube upright, carefully pour a little of the clear limewater into the tube. If you do this gently, carbon dioxide gas will remain in the tube.● With your thumb over the mouth, shake the tube so as to mix the carbon dioxide gas and the limewater.

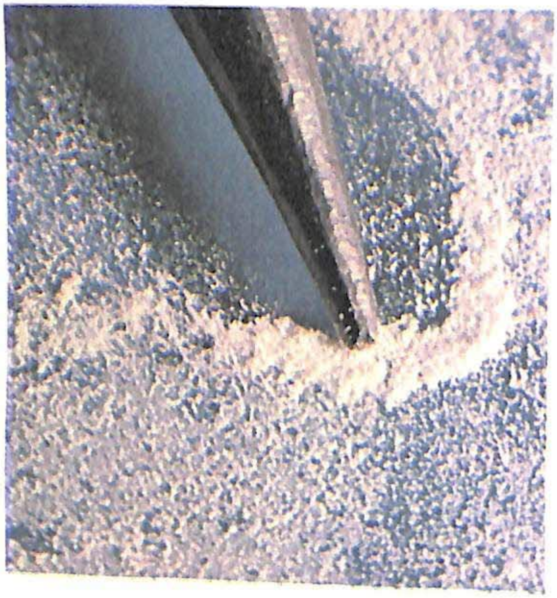
Here is what happened in one trial.▲ What has happened to the limewater?

Cork the other test tube of gas, for use in the next investigation.









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What Is the White Solid?

Limewater turns milky when combined with carbon dioxide. It turns milky because a new substance is formed that is made up of tiny white specks. The specks do not dissolve in water, as sugar does. This white substance can be filtered out of the liquid. It is a white solid. ■

What is this white solid that comes from putting together carbon dioxide and limewater? Let's reason from the evidence. Can this white substance be carbon dioxide? No, for carbon dioxide is a gas. Can the white substance be limewater? No. Limewater is a base, you recall, and turns pink litmus blue. When the pure white substance is tested with litmus paper, it does not change pink paper blue. Nor does it change blue paper to pink. It is **neutral** to litmus paper. The white substance, then, is neither acid nor base. The white substance is not limewater.

Limewater is calcium hydroxide dissolved in water. This white substance is not calcium hydroxide, then. Calcium hydroxide dissolves in water. The white substance does not.

What are some properties of this mysterious substance? It is white. It is a solid. It does not dissolve in water. It is not an acid or base; it is neutral to litmus paper. What is this substance? The investigation on the opposite page will help you to discover for yourself what it is.

Why the Test Works

The white substance that forms in limewater when carbon dioxide is present is calcium carbonate. This is the same substance that eggshells and limestone are made of.

Let's see how this calcium carbonate is formed in limewater. It is produced when carbon dioxide reacts with limewater. Limewater is dissolved calcium hydroxide. So we can write this equation. ●

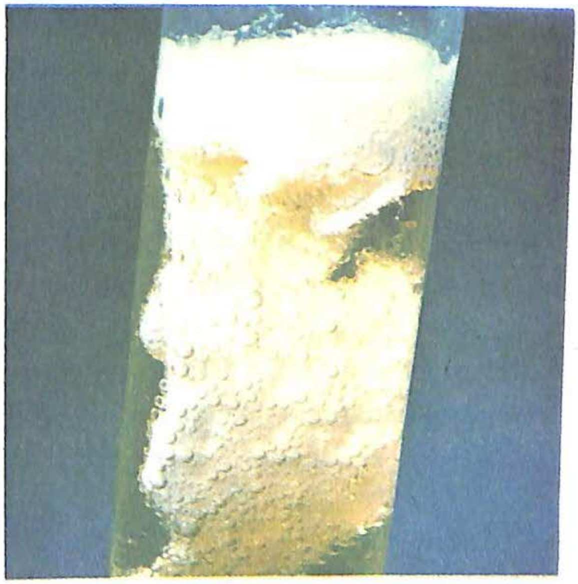
●

carbon dioxide + **calcium hydroxide** ⟶ **calcium carbonate** + **water**
(gas) (limewater) (white solid substance)

AN INVESTIGATION into a White Substance

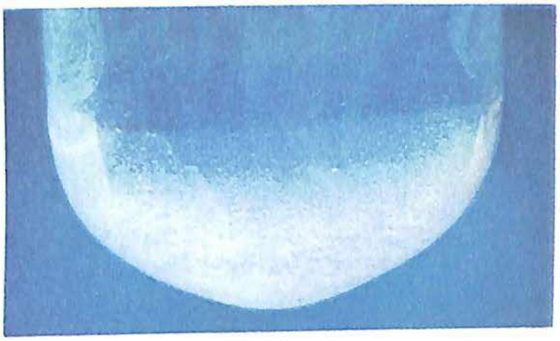
Needed: a test tube of carbon dioxide gas (from the previous investigation), limewater, vinegar, some bits of eggshell, an empty test tube

Put several bits of eggshell into the empty test tube. Add vinegar until the tube is about half full. Observe what happens. Here is what happened in one trial. ■

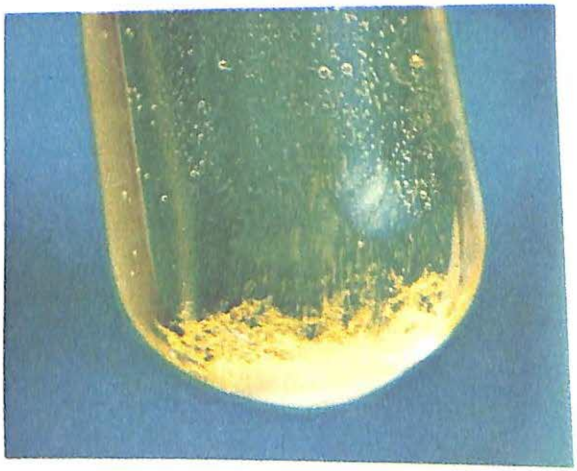


Eggshell is mainly calcium carbonate. When vinegar is added to calcium carbonate, gas is given off. The gas is carbon dioxide, which rises in tiny bubbles.

Now carefully add limewater to the test tube containing carbon dioxide gas, until the tube is about half full. Mix limewater and gas by shaking the tube with your thumb over the mouth. When the limewater has turned milky, showing that carbon dioxide is present, let the white substance settle for about 15 minutes. It will collect at the bottom of the tube. ●

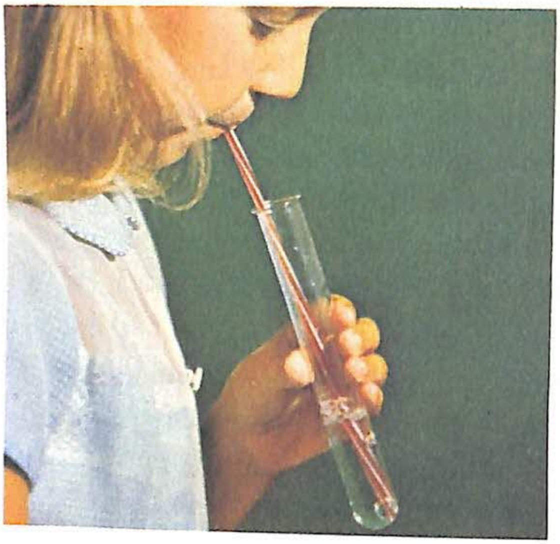


Now add vinegar very gently until the tube is almost full. Carefully pour the vinegar down the side of the tube so that the white substance at the bottom is not disturbed. Look closely to observe what happens between the vinegar and the white substance. It will take a minute or so to start. Here is what happened in one trial. ▲



The gas given off is carbon dioxide, the same gas given off by eggshell.

What is the white substance?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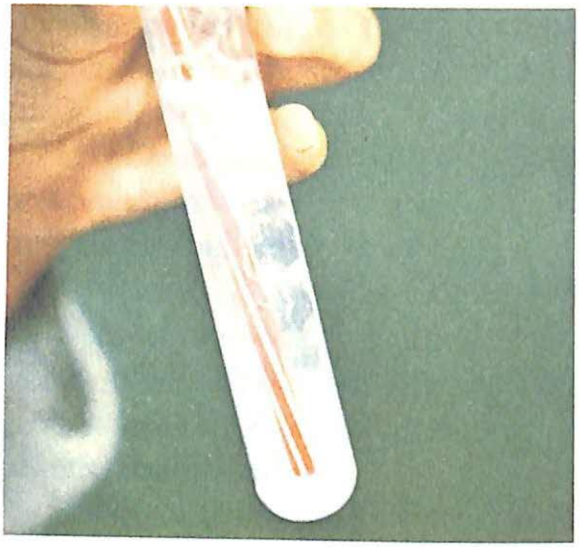
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This evidence suggests that there is not much carbon dioxide in the air.

Now exhaled air is tested. Exhaled air is blown through a straw into the limewater. ■ Has the limewater turned milky? ●

When exhaled air is blown through the limewater, the limewater turns milky. This test shows that exhaled air has much more carbon dioxide in it than inhaled air has. (There is some carbon dioxide in inhaled air, but not enough to turn the limewater milky.)

The evidence is, then, that you make carbon dioxide within you.

You are a living thing. Do other living things produce carbon dioxide? See for yourself by doing the investigation on the opposite page.

Where Does the Carbon Dioxide Come From?

You make carbon dioxide. Lima bean seeds make carbon dioxide. Fish make carbon dioxide. In fact, most plants and animals make carbon dioxide.

What is needed to make carbon dioxide? Let's reason it out, and write the equation for it. Carbon dioxide is an oxide, we know. Therefore oxygen must be one of the elements in carbon dioxide. The other element must be carbon. So the equation is:

carbon + oxygen ⟶ carbon dioxide

This is an example of **oxidation** (ok′sə·dā′shən), that is, the combining of a substance with oxygen.

You produce carbon dioxide, and this reaction is going on in you. In fact, oxidation is going on in any living thing. It is oxidation that produces carbon dioxide.

We know that animals and plants take in air. We know that air is about one-fifth oxygen. Animals and plants get oxygen from the air for oxidation.

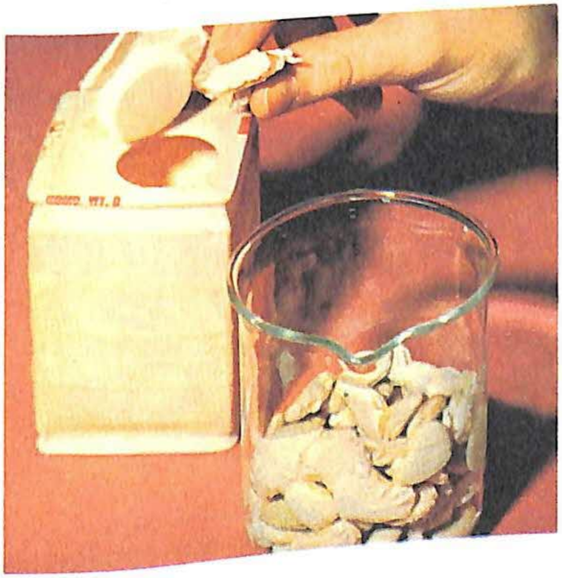
AN INVESTIGATION into Whether Soaked Seeds Produce Carbon Dioxide

Needed: small empty milk carton, cotton, about 1 pint of dried lima bean seeds which have been soaked for 2 or 3 hours in water, limewater in a glass

Put a layer of cotton about an inch thick in the bottom of the generator carton. Add enough water to soak the cotton. Put in the soaked lima beans.■ When the carton is about full close the cap tightly. Make a tight-fitting hole in it for the delivery tube. Put the end of the tube in the limewater.● Let stand overnight. Then squeeze the sides of the carton gently, to force the gas into the limewater.

Here is what happened in one trial.▲

To turn limewater milky and make calcium carbonate, what compound must the beans have produced?



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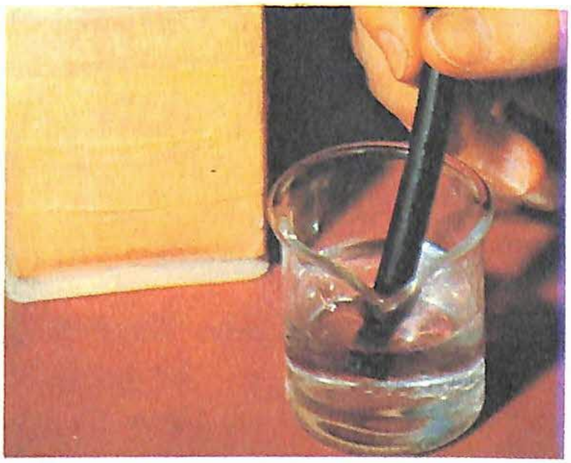
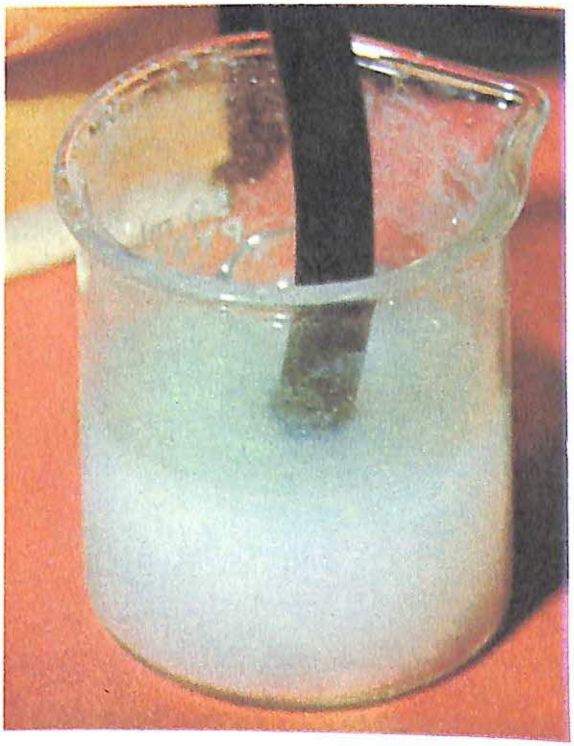
Additional Investigation: How can you show that it was the beans, and not the wet cotton, that turned the limewater milky?





This is a **chemical reaction,** for the atoms have changed places to form new substances. This chemical reaction is a test for carbon dioxide. You will make use of this **chemical test** again and again. Whenever limewater turns milky, this chemical reaction is taking place. Whenever this chemical reaction takes place, the substances shown in the equation on page 70 are present.

This is why scientists can depend on chemical tests. Scientists can tell from the substances produced what substances must have been there to begin with. Wherever you find calcium carbonate, you can be sure that certain elements are present. These elements are calcium, carbon, and oxygen. These elements are the building blocks of calcium carbonate. Whenever limewater turns milky, you know that carbon dioxide must have combined with the calcium hydroxide of the limewater.

Whenever limewater turns a milky color then, you know that carbon dioxide must have been present.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A common compound of carbon that is a gas and is found in air, is
   a. carbon dioxide b. calcium carbonate
2. When carbon dioxide is bubbled through limewater, the limewater
   a. turns milky b. remains clear
3. When calcium hydroxide turns milky, the substance formed is
   a. carbon dioxide b. calcium carbonate
4. Carbon dioxide + calcium hydroxide ⟶
   a. calcium carbonate b. limewater

B. Write a short paragraph or two on this topic: "A Test for Carbon Dioxide."

USING WHAT YOU KNOW

Soda water (such as is put in soft drinks and ice cream sodas) has a gas dissolved in it. When soda water is poured into a glass, bubbles of the gas appear.

One boy took a little plain soda water and added it to limewater. A milky white substance formed. What compound must have been present? How do you know?

ON YOUR OWN

With your teacher's help and a pair of tongs, put a small piece of Dry Ice in a glass of water. **Do not touch Dry Ice with your hands. It can freeze the tips of your fingers.**

What happens?

Test the gas with (1) litmus paper, (2) limewater.

6. A Compound Living Things Produce

You breathe in air. That is, you **inhale** air. When you breathe out, you **exhale.** However, the air you exhale is not the same as the air you inhale.

Let's look at some evidence. A little limewater is poured into a test tube. Above the limewater in the tube there is air. It is the same kind of air that you inhale. The tube is shaken so that the air and limewater mix. Has the limewater turned milky? ■

You can see that there is not enough carbon dioxide in the air in the tube to turn the limewater milky.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Most living things produce
   a. oxygen b. carbon dioxide
2. Compared with exhaled air, inhaled air has more
   a. oxygen b. carbon dioxide
3. Compared with inhaled air, exhaled air has more
   a. oxygen b. carbon dioxide
4. When food is oxidized, it combines with
   a. oxygen b. carbon dioxide

B. Write a paragraph or two on this topic: "A Chemical Test That Shows Oxidation of Food in the Body."

USING WHAT YOU KNOW

1. What is missing in this equation?

$$\textbf{carbon} + \textbf{?} \longrightarrow \textbf{carbon dioxide}$$

2. A candle was placed in a jar of exhaled air. The candle could not be lit. Can you explain why?

ON YOUR OWN

Can carbon dioxide be poured? Plan an investigation to find out. With your teacher's permission, carry out the investigation.

7. A Chemist's View of the Earth

You have been studying a few of the Earth's numerous elements and compounds. Now let's look at the Earth as a chemist might see it. What are the main elements and compounds the chemist finds in and on the Earth?

By careful testing, the chemist has found out what elements and compounds are in the Earth's crust. He knows what elements and compounds are in the waters of lakes, rivers, and oceans. He knows the elements and compounds in the atmosphere. 🟦 His knowledge has come from the hard work of many scientists, from many years of work and from many careful tests.

See if you can answer these questions, using information in the table below.

Which element is most common in the Earth's crust? in the waters? in the air?

Which element is more common in the crust, aluminum or iron?

🟦 COMMON ELEMENTS IN LAND, WATER, AND AIR

Elements in 100 pounds of the Earth's crust		Elements in 100 pounds of the Earth's waters		Elements in 100 quarts of the Earth's air	
oxygen	46.7 pounds	oxygen	85.0 pounds	nitrogen	78 quarts
silicon	27.7 pounds	hydrogen	10.7 pounds	oxygen	21 quarts
aluminum	8.1 pounds	chlorine	2.1 pounds	argon	0.94 quart
iron	5.0 pounds	sodium	1.2 pounds	neon	0.02 quart
calcium	3.7 pounds	magnesium	0.14 pound	other gases	0.04 quart
sodium	2.7 pounds	sulfur	0.09 pound		100.00 quarts
potassium	2.6 pounds	calcium	0.05 pound		
other elements	3.5 pounds	potassium	0.04 pound		
	100.0 pounds	other elements	0.68 pound		
			100.00 pounds		

These figures are averages.

Oxygen is a gas. What element that is *not* a gas makes up more than 25 pounds of 100 pounds of the Earth's crust?

About how many quarts of air must you inhale and exhale to get 1 quart of oxygen, and about how many to get 1 quart of nitrogen?

Substances in the Earth

Nearly half of the Earth's crust is oxygen. Oxygen is a gas. Yet the Earth's crust is a solid. How can we explain this large amount of oxygen in the Earth's crust? Is the Earth's crust filled with this gas?

Recall that oxygen combines readily with other elements, to form oxides. For instance, iron and oxygen combine to form iron oxide, or rust, which is a solid. Aluminum and oxygen combine to form aluminum oxide, another solid. There is a great deal of silicon dioxide in the crust. In fact, you may have dug shovelfuls of it, for sand is silicon dioxide.

Oxygen, you see, is a very **active** substance. That is, it combines readily with other substances. So oxygen is found mainly combined with other elements, in compounds. You won't find lumps of pure iron or pure aluminum in the crust of the Earth. You will find iron and aluminum compounds, for most elements have combined with other elements, especially oxygen.

Substances in the Waters and the Air

Chemists have studied the elements and compounds in the waters of the Earth—the rivers, lakes, and oceans. Here, too, the most common element is oxygen, as the table shows. Indeed, there is almost six times as much oxygen as all the other elements in the waters.

How is oxygen held in the waters of the oceans and lakes? Most of the oxygen is combined with hydrogen. It makes an oxide of hydrogen—hydrogen oxide. Of course this compound is better known as water.

Most of the sodium in the oceans is combined with the element chlorine. This makes a compound, sodium chloride, which we have on our dining tables. It is the salt we use to season food.

There are elements and compounds in the air, too. Two elements make up almost all of the air, as the table shows. These elements are nitrogen and oxygen. Most of the nitrogen in the air around us has not combined with any other element. Nitrogen does not combine easily with other elements. It is a fairly **inactive** gas, that is, it does not combine easily.

There is plenty of oxygen in the air that has not combined with other elements. However, as you know, oxygen does combine easily. Oxygen is an active gas, in other words.

We breathe air. Inside our bodies, oxygen in the air we breathe combines with substances in our food. It is this combination of oxygen and food, taking place in our bodies, that yields us energy. Without oxygen we could not live for more than a few minutes.

Many living things besides ourselves take in oxygen and use it for energy. ■ These water insects take along an air bubble. ● How is it, then, that all the oxygen in the air was not used up long ago? Luckily, oxygen goes back into the air all the time. You will see later on how this happens.

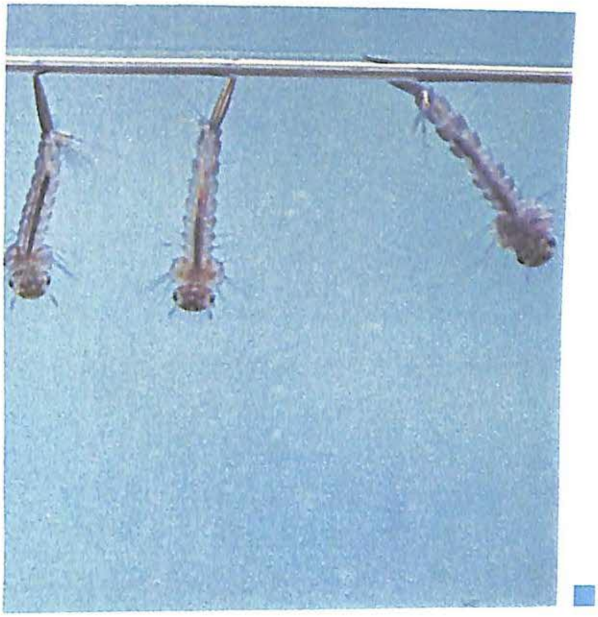
Our Store of Elements

We have the elements of the Earth all around us. We combine atoms of these elements to make different molecules. We break up molecules to get different elements. Elements are most important, then. What is our store of elements?

There are ninety-two elements found naturally in the Earth. Scientists have made eleven new elements in addition to the ninety-two elements that exist around us. Scientists have found eleven new building blocks to go with the ninety-two building blocks we have.

Some of the elements are much more common than others. In fact, a very large part of the Earth's crust is made up of only seven elements, as the table on page 77 shows.

On the following pages are listed some of our most important elements, some of their properties, and some uses we make of them.



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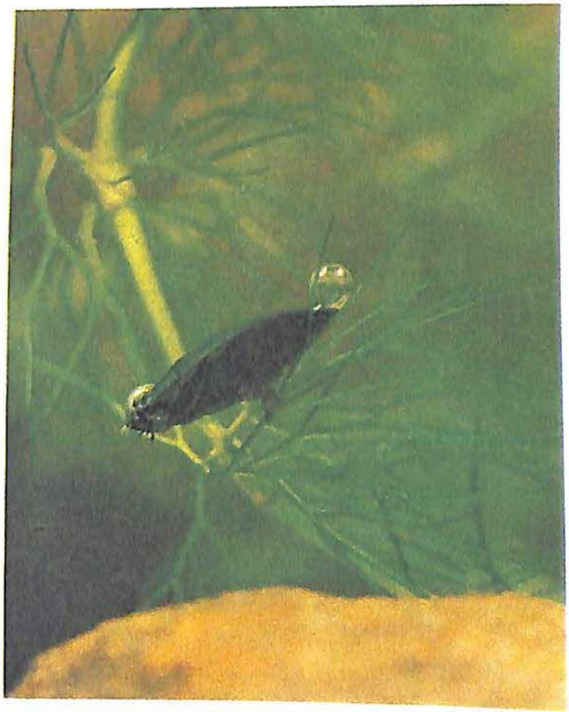

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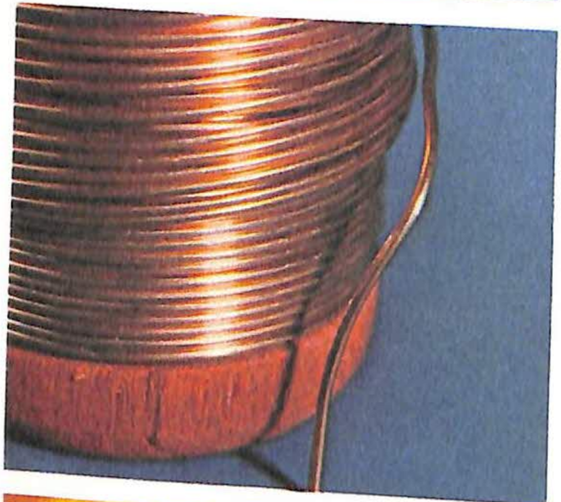

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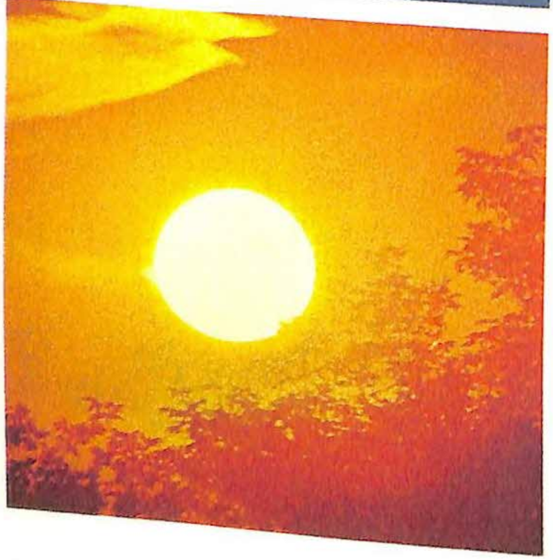

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A Dozen Important Elements

1. *Aluminum* is a silvery-colored metal and very light. Like most metals, it is shiny and can be bent and worked. Aluminum is not found free in the ground. It must be obtained from its compound, aluminum oxide. What do you have at home that is made of aluminum?

2. *Carbon,* like hydrogen, is present in all living things. Carbon is usually black. Coal is mainly carbon, so is soot. ■ A diamond is pure carbon. Do you have any objects made of carbon in your home?

3. *Chlorine* is a green gas. It is poisonous. Yet you eat a compound containing the element chlorine every day. Salt is sodium chloride, a compound made up of the elements sodium and chlorine. When atoms of different elements combine, the compound is often useful. The sea is salty mainly because of sodium chloride.

4. *Copper* is a metal that has a reddish luster. It was one of the first metals that man learned to use. As you know, it can be worked into pots and pans and wire, among other things. ● Brass contains copper.

5. *Helium* is a colorless and odorless gas. It is lighter than air, like hydrogen gas, but it doesn't burn, as hydrogen does. A quart of helium

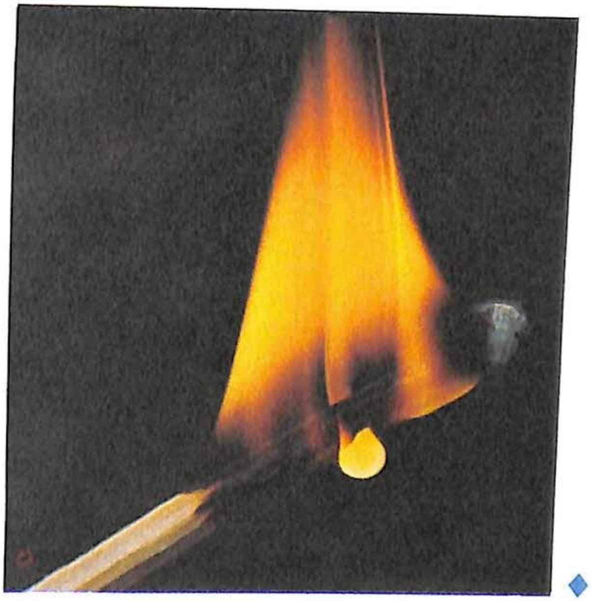
weighs four times as much as a quart of hydrogen. It is the changing of hydrogen into helium that produces energy in the Sun.▲

6. *Hydrogen* is another colorless and odorless gas. Hydrogen atoms are an important part of all the fuels we use.◆ Of course hydrogen is an important part of that very useful compound, water.

7. *Iron* is the most often used metal. We get it from iron oxides, of which this iron ore is a sample.★ Iron combined with carbon forms steel. Steel combined with other metals forms substances of useful qualities, such as stainless steel. What things made of iron or steel do you have in your home?

8. *Nitrogen* is a colorless and odorless gas. It makes up about $\frac{4}{5}$ of the air you are breathing. Nitrogen is an important part of the meat, cheese, and fish that we eat. You and all other living things are made up mainly of these four elements: carbon, hydrogen, oxygen, and nitrogen.

9. *Oxygen* is still another colorless and odorless gas. Every breath you take is important because you breathe in oxygen. It is perhaps the most important gas for all living things, and makes up about $\frac{1}{5}$ of the air. Without oxygen, fuels like gasoline and oil and coal would not burn.◈ Do you know any metals that do not combine with oxygen?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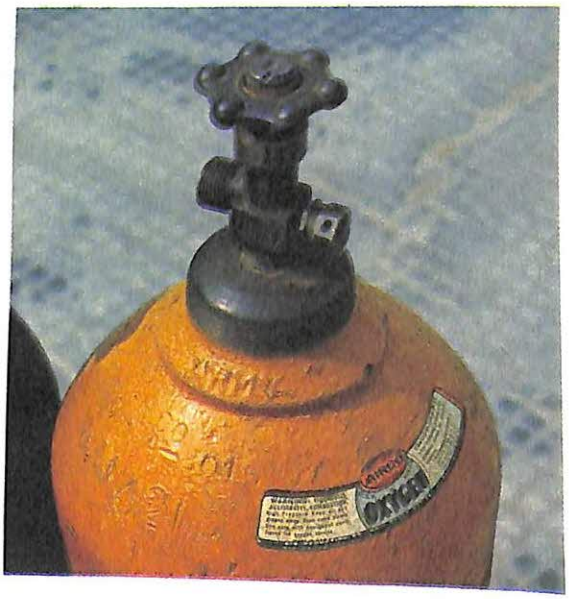

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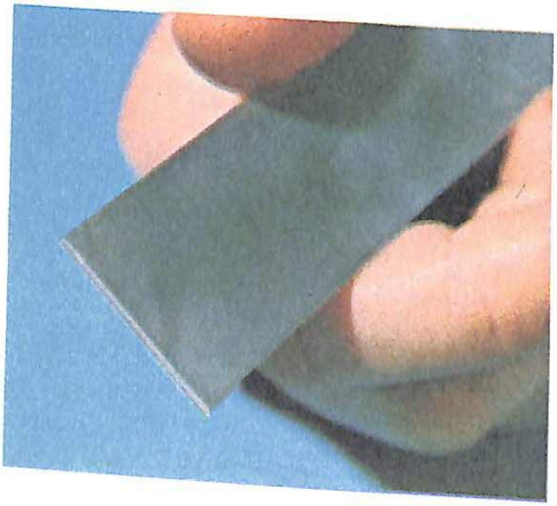

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10. *Sulfur*, found as crystals, is not a metal. ■ However, it can combine with many different metals. Sulfur can combine with zinc, for example. It forms white zinc sulfide, which is very useful in paints. Sulfur combines so easily with metals that it tarnishes many of them. Silver blackens, for instance, as it combines with gases having sulfur in them.

11. *Uranium* is one of the heaviest metals, more than twice as heavy as iron. It is used for producing atomic energy. You may remember that it is radioactive: its atoms break up.

12. *Zinc* is a silver-gray metal. ● When iron is coated with zinc, the iron is protected against rusting and is called galvanized iron. Zinc is an important part of many dry cells and batteries, in which chemical energy becomes electrical energy.

BEFORE YOU GO ON

Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Which of these elements is the more common in the Earth's crust?

a. oxygen
b. aluminum

2. Which of these compounds is the more common in the crust?

a. silicon dioxide
b. calcium oxide

3. Which of these compounds is the more common in the waters?

a. hydrogen oxide
b. carbon dioxide

4. How many elements are there?
   a. about fifty   b. about one hundred

USING WHAT YOU KNOW

1. Which of these gases is inactive in the air, oxygen or nitrogen?

2. Is aluminum oxide or sodium chloride more common in the waters?

3. Why are there so many oxides in the Earth's crust?

4. What seven elements are the most common on Earth?

ON YOUR OWN

If you live near the sea, put a pint of sea water in an open pan and let it evaporate. Let a pint of water from the faucet evaporate as well, in another pan.

How much more solid material is there in sea water than in tap water? How can you find out the answer to this question?

8. More Weight or Less?

Take a quart jar and put some steel wool in it. The bottle already has air in it, of course. So two elements, iron and oxygen, begin in the jar a chemical reaction that we have met before:

iron + oxygen ⟶ iron oxide

Adding a few drops of water to moisten the air in the bottle will help the reaction go faster. Cap the bottle tightly. ▲ Rust, iron oxide, is forming. There is nothing unusual about this. You have seen it before.

However, there is something here that you may not have noticed. There is an interesting problem. As iron and oxygen combine to make iron oxide inside the bottle, does the weight inside the bottle change?

▲

After all, a new substance is being formed inside the bottle. Oxygen in the air is combining with iron from the steel wool to form iron oxide. Will this make the substance in the bottle weigh more or less? Can you reason out an answer from what you know?

Does the Weight Change?

Let's investigate the problem. A sensitive balance can give us some evidence. ■ On one side rests the closed bottle of steel wool and moist air. On the other side rests a weight that just balances the weight of the bottle.

What will happen if the bottle gets heavier? The leveled balance will tilt as the bottle pulls it down, of course.

If the bottle gets lighter, the balance will tilt the other way as the bottle moves up.

The bottle is left standing on this balance for several days. A good deal of rust forms. Has the balance tilted? ●

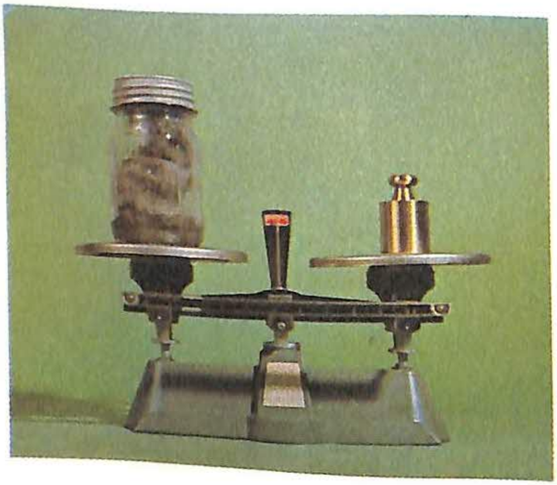
Has the weight changed?

You can see that the balance shows no change of weight. Chemists have found, by many experiments with the best balances, that the weight does not change. Chemists have found that when iron and oxygen combine,

the weight of the iron +
the weight of the oxygen
= the weight of the iron oxide

The iron and the oxygen do form a new substance, iron oxide. But the oxide has just the same weight as the iron and oxygen that combined to form it. No new matter is formed. No matter is lost, either. No atoms have been gained, no atoms have been lost. There are just as many atoms in the bottle at the end as in the beginning. But some of them have combined in a new way, to make a new substance. ▲

■



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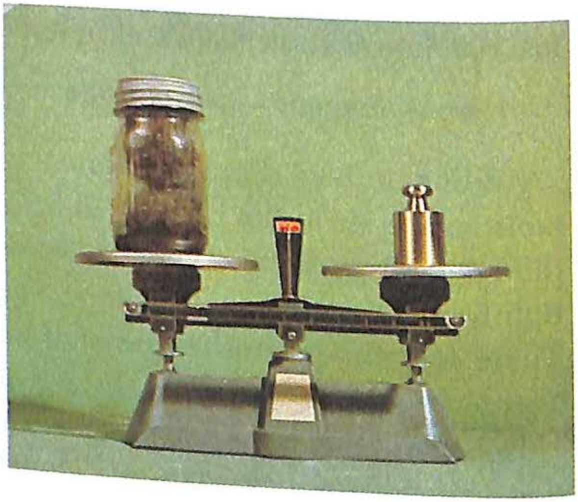
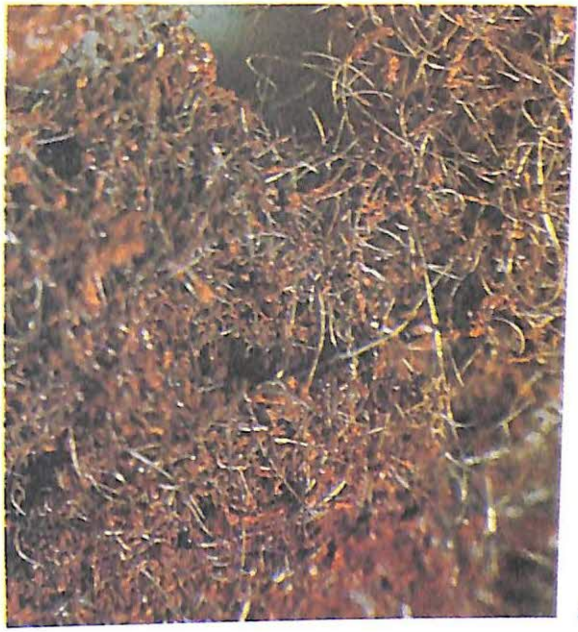


No matter is added, no matter is lost as iron and oxygen become iron oxide. The same thing is true for all chemical reactions. **In a chemical reaction, matter is neither gained nor lost.** The atoms change places.

When we use very special methods (as when an atomic bomb explodes) then some matter *is* lost. Then matter disappears—and becomes energy, as you shall see. But in the ordinary chemical reactions that go on around us every day, matter is neither gained nor lost.



BEFORE YOU GO ON

The main concept of this section is contained in the answer to this question: In ordinary chemical reactions, is matter gained or lost?

Explain your answer and give an example.

USING WHAT YOU KNOW

1. The elements iron and sulfur can combine to form a compound, iron sulfide. Suppose that 56 pounds of iron and 32 pounds of sulfur are used. All of the iron and all of the sulfur combine. How much iron sulfide is formed?

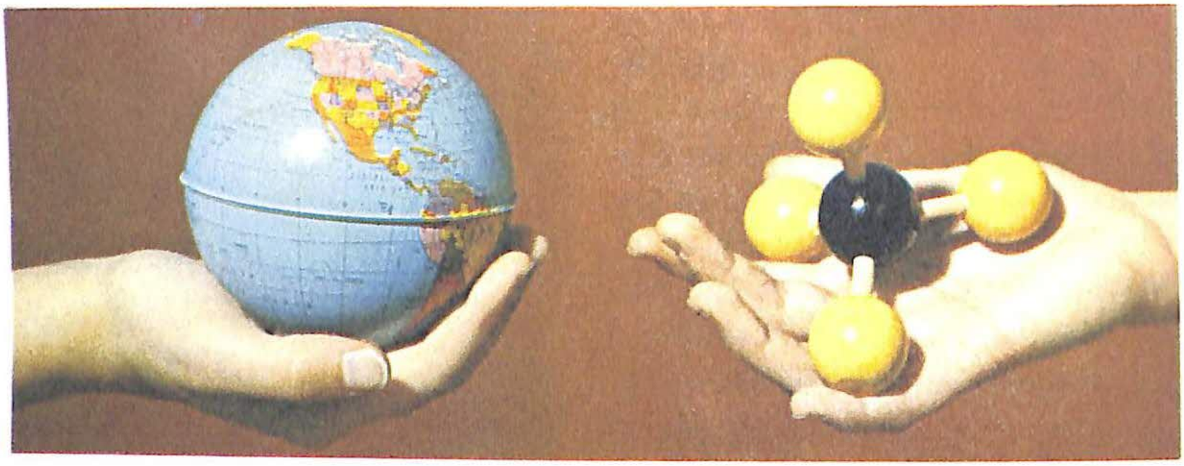
2. You know this reaction:

$$\textbf{iron} + \textbf{oxygen} \longrightarrow \textbf{iron oxide}$$

Suppose that 72 pounds of iron oxide were made, and 16 pounds of oxygen were used to make it. Then

$$\begin{array}{ccc} \textbf{iron} + & \textbf{oxygen} \longrightarrow & \textbf{iron oxide} \\ ? & \text{16 pounds} & \text{72 pounds} \end{array}$$

How much iron was used?



9. The Main Concept: The Earth's Building Blocks

Different scientists look at the world in different ways.

A geologist, for instance, looks at the Earth as a planet. The geologist's world is big. He can climb and walk over the things he studies.

The chemist has another way of looking at the world. The chemist's building blocks are so small that they can't be seen. He works with atoms. He combines elements into compounds and breaks down compounds into elements. By building up compounds and breaking them down he tries to find out what the world is made of.

A compound is made up of at least two different elements. Iron oxide, for example, is a compound. It is made up of the elements iron and oxygen, in this chemical combination:

iron + oxygen → iron oxide

A chemical reaction means that a change has taken place. In a chemical reaction, compounds may be broken down into elements. Or elements may be combined to make compounds. The kind of change which takes place in a chemical reaction is called a **chemical change.**

In a **physical change,** only the form of the substance changes. For example, ice changing to water is a physical change. Only the form of the water has changed, from solid to liquid. Tear up a piece of paper and you have made a physical change in the paper. But burn the paper, and new chemical compounds form. When new compounds form, a chemical change is taking place.

Whatever the chemical change may be, one thing is certain. Whether elements are combining or compounds are breaking down, the amount of matter put into a chemical reaction is the amount that comes out. Matter has been neither gained nor lost.

Fixing the Main Concepts

TESTING YOURSELF

A. Test your understanding of important concepts in this unit by doing these problems.

1. Ammonia is a compound made up of the elements nitrogen and hydrogen. Is the molecule of ammonia larger or smaller than either of the atoms which make it up?

2. Substance X is tested with blue litmus. The blue litmus remains blue. However, pink litmus is turned blue by the substance. To what class of substances does X belong?

3. One pound of copper sulfide is broken down into its elements. What must the two elements together weigh?

4. The element mercury can be combined with oxygen.

mercury + oxygen ⟶ mercuric oxide

Suppose that one pound of mercury is used. Would the mercuric oxide weigh more or less than one pound? Why?

B. Test your understanding of concepts in this unit by using each of these key words and phrases in a sentence.

element
compound
atom
molecule
chemical reaction
chemical change
chemical test
oxide
oxidation
acid
base

C. Test your knowledge with this quick check.

1. On this planet Earth, the number of elements is about
   a. 25
   b. 50
   c. 75
   d. 100

2. The smallest part of a compound that has the properties of the compound is

a. an element
b. an atom
c. a molecule
d. a substance

3. Scientists classify a solution which turns pink litmus blue as

a. acid
b. base
c. oxide
d. solid

4. In an ordinary chemical reaction, matter is

a. lost
b. gained
c. almost all destroyed
d. neither gained nor lost

5. In the Earth's crust, the compounds found in the greatest amount are

a. acids
b. bases
c. oxides
d. gases

ON YOUR OWN

Keep a notebook titled "New Work in Science." Scientists are at work adding to knowledge. Their work is often reported in newspapers and magazines, and on television. Watch for new developments and discoveries. Record them in the notebook. For instance, when will element 104 be discovered? element 105? Who will discover it, and what properties will it have?

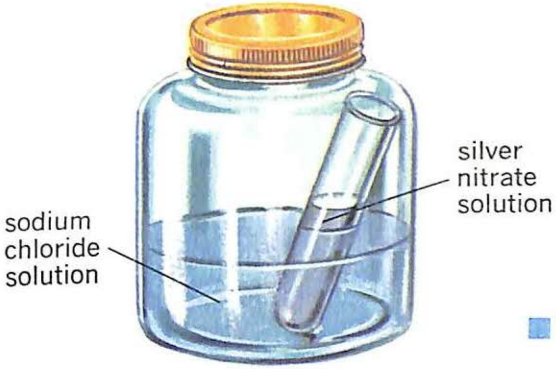
A notebook of this kind can be very useful for keeping you up-to-date in science. You may want to share your notebook with your classmates.

FOR YOUR READING

1. *The First Book of Science Experiments*, by Rose Wyler, published by Watts, New York, 1952. If you'd like to do more investigations with different elements and compounds, you will find a good number of investigations in this book.

2. *Let's Find Out*, by Herman and Nina Schneider, published by W. R. Scott, New York, 1946. Although this book is not new, the investigations are very interesting. The ideas the investigations deal with are ones which will be with us for some time.

3. *It's Fun to Know Why*, by Julius Schwartz, published by McGraw-Hill, New York, 1952. This book explains the "why" of many things in the world around you.



GOING FURTHER

An Investigation

The compound sodium chloride is common table salt. It is made up of the elements sodium and chlorine.

Recall that carbon dioxide, iron oxide, and aluminum oxide belong to a class of substances called oxides. Sodium chloride belongs to a class of substances called chlorides.

There is a chemical test for a chloride. Take a small amount of the substance which is thought to be a chloride, and add a small amount of silver nitrate. When silver nitrate is added to a chloride, a white curdling substance is formed. This substance is silver chloride. That is,

sodium chloride + silver nitrate ⟶ silver chloride + sodium nitrate

Place a pinch of salt in some water in a jar. The jar should have a screw cap which can be closed tightly. Put some silver nitrate solution in a test tube, and prop it up in the jar, as shown. ■ Cap the jar tightly.

Now turn the jar over, so that the silver nitrate and sodium chloride mix. White silver chloride forms.

Does the jar weigh the same after the reaction as it did before? How do you know?

CONCEPTUAL SCHEME

When energy changes from one form to another, the total amount of energy remains unchanged.

Unit Three

THE EARTH IN ORBIT

(*Text pages 90–137*)

UNIT CONCEPT

Energy must be applied to produce an unbalanced force, resulting in motion or change of motion.

The child gains an understanding of the orbitry of planets and satellites; he begins to appreciate that tremendous amounts of energy must be applied to get a satellite or space ship into space.

A VIEW OF THE UNIT

A Preview of the Concepts

During a study of space, a fifth-grader observed that the way the Moon goes around the Earth is the same as that of space capsules and satellites. This unit undertakes to show how correct the child's reasoning really was.

The unit introduces and illuminates the basic principles by which children can understand the orbiting of planets and satellites. The children move gradually toward comprehension of Newton's laws of universal gravitation and motion. Similarly (in relation to orbiting) they are introduced, through a development at their level, to theories of the origin of our solar system. As with succeeding units, this unit gives children an insight into the work and contributions of scientists; for example, Galileo and Newton.

The unit confronts children with the force of gravitation. Such analysis is necessary for understanding why *energy must be used* to cause objects to go into motion. Prior to this unit (in other books of this series—particularly *Concepts in Science* 2, 3, and 4—children have studied transformations of energy and the uses of energy in doing work. Now children consider relationships between energy, the force of gravitation, and the motion of objects on Earth and in space.

Gathering Resource Materials

NASA (National Aeronautics and Space Administration, Washington, D. C. 20025) publishes charts, pictures, and pamphlets on space developments. If you live in a community which has a classified telephone book, check under such headings as missiles and rocket manufacturers, space research and development, for listing of local resource industries. A local hobby store may have model construction kits of space vehicles.

Occasionally, materials such as colored charts are available from prime contractors. You may wish to select one child to correspond with some of the following sources, whose main offices are given.

AiResearch	Los Angeles, California
Boeing	Seattle, Washington
Douglas Aircraft	Santa Monica, California
General Dynamics	San Diego, California
McDonnell Aircraft	St. Louis, Missouri
North American Aviation	El Segundo, California
Grumman Aircraft	Bethpage, Long Island, New York

SUPPLEMENTARY AIDS

Films

All films and filmstrips are in full color. Those rated "Intermediate" are on an average level for children studying this textbook. Those rated "Primary" or "Junior High" are respectively easy or advanced for the grade. Names and addresses of distributors and suppliers are on page F–25.

Asteroids, Comets, and Meteorites (11 min.), F.A. Shows how astronomers have learned about these objects traveling around the Sun; what each group looks like; place of each in solar system. Also shows man-made, or artificial, satellites. (Intermediate)

How We Know the Earth Moves (11 min.), F.A. Demonstrates and explains the Foucault pendulum by which Earth's rotation was first proved. How astronomers determine Earth's solar orbit. (Intermediate)

Earth in Motion (12 min.), Cenco, 1963. Explains that the Earth moves in three different ways: it revolves on its own axis; it travels in a circular path around the Sun; and, as a part of the whole solar system, it moves around in our galaxy. Explains the periods—day and night, a year, and the different seasons. (Intermediate, Junior High)

Earth Satellites (12 min.), Cenco, 1963. Explains what a satellite is and how it stays in orbit. How man has put satellites in orbit. Tells of Russian and American satellites and how they are proving useful to man. (Intermediate, Junior High)

The Moon (12 min.), Cenco. Describes physical characteristics of the Moon, its phases, and the effect of its gravitational pull on the oceans, causing tides. (Intermediate, Junior High)

A Trip to the Moon (17 min.), E.B.F. An imaginary trip to the Moon shows its surface. Also includes footage of the Russian lunar probe to the heretofore "dark" side of the Moon. Animated models clarify the relationship of the Moon to the Earth. (Intermediate, Junior High)

Gravity: How It Affects Us (14 min.), E.B.F. Shows how gravitation can be used to do work, how it affects our daily lives, and how it would affect a human being in space or on other planets. (Primary, Intermediate)

Filmstrips

The Earth's Atmosphere (39 frames), Jam Handy, 1961. The atmosphere, held to the Earth by gravitation, moves with the Earth as it rotates around the Sun. Difficulties to overcome for space travel; what man has learned from satellites. (Intermediate)

What Is Air Pressure? (39 frames), Jam Handy, 1961. Air pressure is caused by gravitational force on air and movement of air molecules; can be measured; simple experiments. (Intermediate)

Earth's Nearest Neighbor (45 frames), S.V.E., 1956. An imaginary exploration of the Moon. Measures the basic needs of the human body against conditions on the Moon. How to meet these situations. (Intermediate)

The Sun and Its Family (46 frames), S.V.E., 1956. Reviews concepts of planets, asteroids, comets, and other bodies of solar system. Explains the action and meaning of gravitation, solar energy, and the seasons. (Intermediate)

Pictures in the Sky (46 frames), S.V.E., 1956. A number of easily found constellations are presented. Explains why different stars are seen in summer and winter. Of special interest to star watchers. (Intermediate)

Why the Seasons (30 frames), S.V.E., 1960. Explains how Earth's relationship to Sun produces the seasons; summer and winter solstices; spring and fall equinoxes. (Intermediate)

How Earth's Movements Affect Us (61 frames, with sound), S.V.E., 1965. Shows the relationship between the Earth and the Sun; the importance of the 93 million miles that separate the Earth from the Sun; how the turning of the Earth on its axis causes night and day; what causes seasonal changes. (Intermediate)

How Man Explores Space (60 frames, with sound), S.V.E., 1965. Colored photography and drawings show how 25,000 m.p.h. speed overcomes gravitation; explains rockets and rocket stages; essentials of a space capsule. (Intermediate)

Our Solar System (60 frames, with sound), S.V.E., 1965. Shows the solar system to consist of 9 planets (including Earth, 31 moons, 50,000 miniature asteroids, and meteor particles). (Intermediate)

The Sun and Its Energy (50 frames, with sound), S.V.E., 1965. Explains that the Sun is made of fiercely hot gases; how it releases energy; how this energy reaches earth; and how we use it. (Intermediate)

Science Reading Table

Starred titles are considered especially useful for use with this textbook. Names and addresses of publishers are on page F–24.

**Rockets into Space* by Alexander L. Crosby and Nancy Larrick, Random House, 1959. A brief historical account of rocketry from its development by the Chinese over a thousand years ago to space exploration by the Soviet Union and the United States. The continuity of the accumulation of scientific knowledge is apparent. (Easy)

Our World of Science by Duane Bradley and Eugene Lord, Lippincott, 1959. Easy investigations to introduce pupils to the world of physical science. Several investigations are described for the topics air, water, change, motion, sound, light, heat, and electricity. (Average)

A Physics Lab of Your Own by Steven J. Marj, Houghton Mifflin, 1964. Contains seventy investigations arranged to lead the junior scientist through a step-by-step study of the basic laws of physics. Materials required are inexpensive and readily obtainable. Simple laboratory techniques and methods are described. (Advanced)

Moon Trip by William Nephew and Michael Chester, 1958, paperback by TAB Books, an affiliate of Scholastic Magazines, published by arrangement with G. P. Putnam's Sons. Following a brief introduction on Moon exploration as the new frontier and of the power necessary for takeoff and return, the reader is invited to be a passenger on a space ship going to the Moon. The interesting account of the trip is based on scientific knowledge. (Average)

What Is a Solar System? by Theodore W. Munch, Benefic Press, 1961. Contains facts and figures about the planets, comets, meteors, meteorites, and moons of our solar system, for beginning study. Our solar system in relation to the universe is touched upon. (Average)

Tasty Adventures in Science by Sally Fox, Lantern Press, 1963. Children may have their science and eat it, too, when they perform the investigations described. Simple materials and clearly stated directions for investigating a wide variety of science topics. Each investigation involves the use of something edible. (Average)

What Is Space? by Elmer R. Kane and Merill C. Fellger, Benefic Press, 1962. A "once-over lightly" account of what we know about space, its probable characteristics, and the tools and methods used for space exploration and study. Useful for initial examination of the topics involved in space science. (Average)

The Story of Planets, Space, and Stars by Gaylord Johnson, Harvey House, 1959. A comprehensive account of the universe. The contributions of Galileo, Lippershey, Kepler, Newton, and Herschel to astronomy are described. The major portion of the book provides a scientific basis for a brief concluding section on travel in outer space. Average readers with particular interest in astronomy will enjoy the detailed account. (Advanced)

°*Satellites in Outer Space,* Revised Edition, by Isaac Asimov, Random House, 1964. Simplified but exceedingly lucid description of basic facts necessary for understanding of natural and artificial satellites of the Earth. Purpose and accomplishments of space probes by the Soviet Union and the United States are explained. An excellent reference for study of assigned subtopics by less capable readers. (Average)

▶ INTRODUCING THE UNIT

What holds the Moon up in the sky? The answer to a question so typical of primary-grade children also holds for upper-grade children the reasons behind the pattern of our solar system, of our universe.

An understanding of the concepts governing the motions of planets and satellites now permits man to launch and control a course for artificial satellites. These concepts also help to explain why planets appear first in one, then another sector of the sky.

(*Text pages 92–98*)

Section 1: THE PULL OF THE EARTH

Children seek a relationship between the pull of gravitation and the weight of an object. Through investigation, they infer that the greater the mass, the greater the gravitational force it exerts.

SUBCONCEPT

To move an object, energy must be applied to overcome the pull of gravitation.

Processes emphasized

Investigation
Observation
Measurement
Hypothesizing
Theorizing
Predicting
Analysis of data
Library research
Reviewing scientists' ways of work

Equipment and Materials

. . . chalk

Introducing the Concept

To introduce the term *gravitation*, conceal a small piece of chalk in your hand. Drop the chalk in front of the class. Why didn't the chalk go up? (Gravitation pulled it down.)

What is gravitation? Can you touch it, smell it, taste it, or see it? Children will begin to think of gravitation as a force pulling objects "toward the center of the Earth." At this stage accept all useful ideas. The four-year-old, who said, "Gravity is what sticks us to the Earth," was making some first-class inferences.

Why do apples, sticks, and stones all behave alike when they fall? "What goes up must come down"; is this statement true today? What is your G-number? That is, how much force of gravitation is exerted on you when you weigh yourself?

Before starting to develop the concept, encourage reading of the text up to "The Pull of the Moon" and close examination of the illustrations.

After investigating gravitational pull at different places on the Earth, children infer that gravitational pull at the Earth's surface varies very little.

Equipment and Materials

. . . a globe (optional)

Developing the Concept

To enlarge further the concept of gravitation, carry out the investigation on page 95. Or, children who have the equipment may do the investigation at home and report or demonstrate their results. A beam balance or a pan balance may be used in place of the equal-arm balance. Also, two milk cartons of sand (weighed and marked) may be used in place of the 500-gram and 250-gram weights.

Now, on the board, draw a circle labeled Earth—or use a globe. Ask for predictions of what would happen if a ball were thrown into the air in Argentina, in Iceland, in Australia, in South Africa—anywhere over the globe.

Ask questions such as the following and relate children's responses to gravitational pull.

1. What did Newton decide after watching an apple fall? (Gravitation is universal.)
2. What is the *weight* of an object? (The force of gravitation on that object.)
3. How can you find the force of gravitation on you? (Weigh yourself.)
4. Would your weight be about the same in Texas as it is in California? (Yes.) Why? (The force of gravitation on you is about the same.)

We can say that the weight of an object is the G-number for that object to show that it is a measure of the pull of gravitation on the object. The G-number is about the same on the surface of the Earth for you—unless you gain weight by eating or lose weight by dieting!

Understanding mass-weight relationship. Form a piece of modeling clay into a ball and weigh it. Now flatten the clay ball into a thick disk and weigh it again. Has the weight changed? (No.) Has the shape changed? (Yes.) Has the mass (the amount of clay) changed? (No.) Do you think the clay disk will have the same weight on the Moon? (No.) The same mass? (Yes.)

Weight is a measure of gravitational pull on a mass.

Relationship of mass and gravitational pull. You will want to expand the concept of universal gravitation by posing these questions:

Is there gravitation on the Moon? (Yes.) If so, how much would you weigh on the Moon?

Children infer that the greater the mass, the greater its gravitational pull and the greater the energy which must be used to overcome it. The less the mass, the less its gravitational pull. Gravitation is universal.

Refer to the text, pages 94–97. Emphasize that the Moon's pull of gravitation is different from the Earth's. The gravitational pull of the Moon is one-sixth that of the Earth.

Children will likely inquire *why* the pull of gravitation differs on the Earth and Moon. Introduce a discussion of mass and weight. Through this discussion, children should understand the following relationships:

1. The mass of the Moon is a great deal less than that of the Earth.
2. This difference in mass results in the Moon's lesser gravitational pull.

Extending the Concept

What is your weight on the Moon and on some of the other bodies in space? Where possible, it is well to fix the concept by applying it to other situations. In this unit, you may wish to apply gravitational pull on the Moon ("The Pull of the Moon," pages 94 and 96) to other bodies in space. Each child might try to answer the following questions at home:

How much would I weigh?
On the Earth I weigh about ____ pounds.
On the Moon I would weigh about $\frac{1}{6}$ as much, or ____ pounds.
On Mercury I would weigh about $\frac{1}{4}$ as much, or ____ pounds.
On Mars I would weigh about $\frac{1}{3}$ as much, or ____ pounds.
On Jupiter I would weigh about $2\frac{1}{2}$ times as much, or ____ pounds.
On the Sun I would weigh about 28 times as much, or ____ pounds.

Example: A person weighs 120 pounds on the Earth. How much would this person weigh on the Moon? $\frac{1}{6} \times 120 = 20$. The person would weigh 20 pounds on the Moon.

Difference in mass. Encourage children to do some research to determine the relative diameters of the Earth and the Moon. Have them cut out two circular disks, one two inches in diameter (Moon) and the other eight inches in diameter (Earth) to show comparative sizes. How much larger in diameter is the Earth than the Moon? Of course, a two-inch ball and an eight-inch balloon would give the comparative sizes more realistically but the one to four relationship of diameters remains the same. How does the mass of the Earth and the Moon compare? (The Earth has far greater mass—actually about 80 times that of the Moon.

Space biography—who's who in science. Is it not remarkable that a scientist who lived 300 years before the Space Age should have contributed so much to what makes space exploration possible or even thinkable today? Encourage children to read whatever is available about Newton in encyclopedias or library science books and to initiate dramatization of events in his life. It should be emphasized that here was a great mathematician and scientist, who worked with little more equipment than his remarkable mind and paper and pencil. But he was a keen observer of a great many objects and events in the world.

Let the children discuss their notions of a scientist. Emphasize that he need not necessarily work in a laboratory, but he is nevertheless dedicated to his work and possesses an inquiring and imaginative mind.

What did Newton mean when he said, "I stood on the shoulders of giants"? (Have children look up data on Ptolemy, Copernicus, Galileo.)

(*Text page 98*)

Reviewing the Concept

Before You Go On. 1. b 2. b 3. a 4. b

Using What You Know. 1. $\frac{1}{6}$ of your weight on Earth. 2. 10 × 150 pounds (1,500 pounds); his mass would not have changed.

(*Text pages 99–105*)

SUBCONCEPT

Energy must be supplied to develop a force sufficient to overcome gravitational pull.

Processes emphasized

Model building
Observation
Investigation
Hypothesizing
Theorizing
Predicting
Reporting

Section 2: MAN OFF THE EARTH

Children begin to realize that the forces in an object at rest are balanced and that to set the object in motion, energy must be supplied to produce an unbalanced force.

Introducing the Concept

In the previous section you learned that your G-number is whatever you weigh. Remember, too, that if any object has a greater mass, its G-number will be greater. The more you weigh, the harder Earth tugs at you. Can you think of a way to escape that pull—right here in the classroom—if only for a second? Encourage volunteers to demonstrate their ideas. The child who illustrates momentary weightlessness by jumping up and down in place is reasoning correctly. Encourage a small child and a larger one to repeat the exercise. Which one has to use more energy to pull away from Earth? (The heavier child.)

Which takes more fuel, an Atlas or a Saturn rocket? Can you justify naming the Saturn?

Through investigation, children deduce that energy is necessary to supply a force that makes an object move. This is an unbalanced force.

Developing the Concept

Balanced and unbalanced forces. As two children prepare the model balloon-rocket (text page 99), ask the class to read as far as "Tin Cans and Rockets." When children complete the reading, let them draw their own version of the apparatus, marking plainly the opposing forces of *thrust* and *gravitation*. When most children have finished reading, let the two children demonstrate their balloon model.

Have the demonstrators prepare a "repeat performance." Explore the text question (page 99), "Why didn't the model rocket go on?"

When you sense that most of the class understands why the rocket did not go on, pose the next question (text page 100), "Why must there be a force to get something moving?"

Encourage the children to reason out possible answers on the basis of class discussion. The text, "Tin Cans and Rockets," provides an answer.

The difference between balanced and unbalanced forces is often difficult for children to see. Be sure they clearly understand that a force pushing in one direction is balanced by a force pulling in the opposite direction. If another force is added, such as the thrust in the moving balloon, it will move in the direction of the greater thrust: ←— ——→. The original forces are the balanced forces; the added force creates the unbalanced force.

Energy and motion. Ask the children to look about the room and name one object which does not show Earth's gravitational pull. In spite of this pull, how are things raised (set in motion)? If children use such terms as push, pull, energy, thrust, they are moving toward the concept of an unbalanced force acting in one direction.

Place a tin can in full view of the class. Then ask, what keeps it at rest? How could we move it? Accept suggestions offered by the children. Select the answer closest to the illustration in the text (page 101). Let a child kick the can. Ask the children to observe and think carefully. What allowed the can to move? (The energy of the kick provided an unbalanced force. *Note:* In actuality, two forces are unbalanced by the kick if the can is lifted from the ground: (1) The force of the kick is greater than the force keeping the object at rest and the can goes forward; (2) The force lifting the can upward is greater than the balanced forces holding the can to the Earth. These need not be differentiated at this point, but may be referred to in studying action and reaction and motion of satellites.)

Action-reaction. Carry out the jet engine investigation on text page 102. Standards for handling dry ice should be established ahead of time. Urge the use of tongs, pliers, or tweezers. Dry ice should never be handled with bare hands, as burns may result. Dry ice may be obtained from soda fountains, drug stores, or dairies.

Two children who did not take part in the balloon demonstration could be invited to prepare, practice, and demonstrate for the class. Again, encourage prediction and verification as to the outcome. Ask "demonstrators" to repeat the investigation. If the results are not the same, ask why this might be so.

Then ask: What did you do? How did you do it? What happened? What did you find out? Encourage a variety of answers to these questions. Then ask: Did the investigation turn out to be a good way of study-

Equipment and Materials

. . . balloon
. . . medicine dropper
. . . paper cone

From their observation, children reason that energy of motion (an unbalanced force) reacts against th gravitational pull to create thrust

Equipment and Materials

. . . a tin can

Children infer that every action ha an opposite and equal reaction.

Equipment and Materials

. . . pint milk carton
. . . kitchen tongs or tweezers
. . . string
. . . nail
. . . dry ice
(See also the Teacher's Man for *Classroom Laboratory* 5.)

ing action and reaction? Why? Can you suggest other ways? Suggest to the children that they try other investigations, first writing down what they would do and what materials they would use. Their write-ups will be your guide to check the practicality and safety of the suggested investigations.

Children have now begun to relate Newton's principle of action-reaction to the rocket's thrust and to the unbalanced force given the flying tin can. Ask the class to turn to the text pictures (text pages 103–104) to predict what will happen to the ball and the boy. Children can verify their predictions as they read the accompanying text. As a means of evaluating learning, invite the children to diagram a rocket launch showing where *action* and where *reaction* are at work (text page 104).

Extending the Concept

Action-reaction everywhere. Encourage the children to look for pictures, newsclips, models, and realia which illustrate action-reaction in daily life. Encourage planning and organizing a two- or three-dimensional bulletin-board exhibit. Look for illustrations in readers or other textbooks. Can you invent arithmetic problems illustrating balanced and unbalanced forces and action-reaction, e.g., it takes X times more energy to lift 24 lbs. than to lift 8 lbs.

Action-reaction for sports fans. Depending upon the sports interests of your locality and your group, encourage observation and recording of data on examples of action-reaction.

Safety rules and action-reaction. Since upper-grade children often serve on school safety patrols, the relationship of balanced and unbalanced forces and motion is important to understand. For instance, children's study of the relationship of speed as an unbalanced force acting on a motionless object might be the basis of better acceptance of the rule of no running in the corridors.

(*Text page 105*)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. b 4. b

Using What You Know. 1. 36 feet. 2. $\frac{1}{6}$ of 3,600,000 or 600,000 pounds. 3. The jet at the right.

(*Text pages 106–111*)

SUBCONCEPT

To alter the path of a body in space, energy must be applied to affect the relationship between gravitational pull and inertial motion.

Section 3: MAN IN ORBIT

Children, by examining the behavior of objects at rest and in motion, begin to understand how Newton's laws of inertia, motion, and universal gravitation explain the orbit of bodies in space and enable an astronaut to guide his capsule and return to Earth.

Introducing the Concept

In a baseball game, if bases are loaded, do you hit the ball hard or easy? (Hard.) If you want to bunt the ball, how do you hit it? (Easy.) How can you plan where your baseball will go? (By your batting stance and by the energy you put into your swing.) How do you hit a ball to make it go in a straight line? (You can't—air slows its motion and Earth's gravitation gives it a curve.) Can you count on the baseball that you hit always returning to Earth? (Yes.) Why? (Earth's gravitational pull.)

How is it possible for space rockets to escape Earth's gravitational pull? (Enormous thrust.) **How is it possible to plan the path of a space capsule?** (Laws of Inertia and Motion.) **How is it possible to bring the capsule back down to Earth?** (Laws of Motion—action-reaction.)

Processes emphasized

Library research
Model building
Observation
Hypothesizing
Theorizing
Predicting
Analyzing experiences

Developing the Concept

Two kinds of inertia. Secure some heavy balls. Push one across the floor. Does it go in a straight or curved path? Repeat, using different balls, until you sense the children are ready for the generalization that objects in motion tend to keep moving in a straight line. Relate to examples from daily life, e.g., heavy vehicles in motion.

Make a chalkboard heading INERTIA OF MOTION. Below it list other examples of straight-line motion as children suggest them. Again relate other objects to everyday life under a second heading, INERTIA OF REST, and list children's suggestions of classroom objects.

Children gain insight into inertia of rest and inertia of motion by examining familiar objects.

Equipment and Materials

- . . . bowling, croquet, or golf ball
- . . . marbles in a wooden track

To focus reading and study of the text, you may find these questions useful: Who first noticed that objects tended to stay at rest—Galileo or Newton? (Galileo.) How did Newton summarize the behavior of objects at rest and in motion? (Law of Motion, page 108.) What gives a rocket the unbalanced force that puts it in motion? (Hot gases.)

Gravitation and inertia of motion. Lay a bicycle on its side. Lay small objects on the sidewall of one tire. What happens when you spin the wheel? (The objects fly off in a straight line.) A rocket travels straight up from the launching pad. What "bends" it into an orbit, a curved path, around the Earth? Why doesn't it fly off into space like popcorn from a moving merry-go-round?

Children infer that objects in motion tend to move in a straight line but that some force (gravitation) pulls a space capsule into orbit around the Earth.

Equipment and Materials

- . . . bicycle
- . . . assorted small objects

What was Newton's bold guess? (Gravitation is universal.) How did Newton show that gravitational force is pulling upon the Moon, stars, and other planets? (He used mathematics.)

Encourage children to help you draw and label on the board a diagram showing, for example:

Rocket on Pad	**Rocket in Flight**	**Rocket in Earth Orbit**
Inertia of Rest	Inertia of Motion	Motion vs. Gravitational Pull

Applying what they have read and reasoned out, the children should now be closer to answering the text question (page 107)—"How is it possible to plan where a capsule will go?"

that is, it condensed. If children have difficulty seeing that a gas can occupy less space (condense), fill a teakettle with water, heat it to boiling, and let the children note that the gas (water vapor) becomes drops of water on the cool surface of a mirror or aluminum foil. The gas condensed, changed state, and its molecules moved closer together.

The text also states that "each protoplanet got still smaller . . . its heavier substances moved toward its center." How can a whirling motion (rotation) help explain this? Encourage a child to place two marbles of different size in a bowl and gently twirl it. What does he see? (The lighter marble moves out toward the rim farther than the heavier one.)

A rereading of the section "A Cloud of Gas" may be desirable to clinch the central ideas of the theory of the origin of the solar system.

Children begin to sense how scientists and engineers can predict orbits.

What is the shape of the Earth's orbit? Is it a circle or another kind of path? How can we find out? If children have not read ahead, direct their attention to the table on page 116. When is the Earth nearer the Sun? When is it farther away? If the orbit were a circle, would these distances change? Recall that an orbit is a regular, even though invisible, path that can be traced by a line. How would you draw an orbit that is a circle? How would you draw an orbit that is not a circle? Children now should perform the investigation on page 117. (Sections of cardboard from discarded cartons afford a good base into which to set thumbtacks.) Conclude with the question: Why is it so important that engineers planning to launch an astronaut into space know how to plot the orbit of the space capsule? (To know how much force to develop, to direct the capsule, to know where it is, to know when to bring it down.)

Equipment and Materials

- . . . model or picture of a space station
- . . . globe

Extending the Concept

A space station model. Initiate a discussion of space stations by providing a picture or a plastic model of one. Children who watch TV and "read pictures" in magazines know a good deal about space stations. Once a space station is up there, will it stay in one place? (No.) How will it move? (In orbit.) What will keep it going? (Inertia.)

Set a globe beside the space station model or picture. How are these two alike? Among other similarities, both bodies are spinning in space because of the inertia of motion. Both are traveling in a closed curve (ellipse). The space stations will travel around Earth. Encourage children to collect illustrations for the bulletin board from magazines they are allowed to cut up and to report on their findings.

(*Text page 118*)

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. a

Using What You Know. 1. Cloud of gas, protoplanets, planets. 2. The straight-line motion of the Earth is balanced by the force of gravitation between the Sun and the Earth which holds the Earth in orbit. 3. We are held to the Earth by gravitation.

Section 5: MOON IN ORBIT

(*Text pages 119–124*)

Children become aware of the theories which explain the origin of our Moon. They gain an understanding of the position and motion of the Moon in its elliptical orbit around the Earth.

SUBCONCEPT

The position and motion of the Moon are affected by gravitation and inertial motion.

Introducing the Concept

What kind of view have you from Space Ship Earth? What can you see in space? Encourage children to compile a list of bodies in space. Some children will undoubtedly name man-made satellites. When this occurs, challenge them to name Earth's first *natural* satellite.

The son of a famous scientist developed a theory about the origin of Earth's Moon. What was the theory? When will his theory receive its real test? (When men bring back specimens of Moon rock.)

Is Moon's orbit circular or elliptical? Can you explain and demonstrate the reason? What connection is believed to exist between the birth of the Moon and the geography of the Pacific Ocean?

Processes emphasized

Library research
Investigation
Model building
Hypothesizing
Theorizing
Predicting
Reporting
Field trips

Developing the Concept

George Darwin's theory. After children have read their text through the "Birth of the Moon," ask: Can you think of ways to show how much the Moon has moved away from us since last year? The year before? How far will it have moved when you are in high school? In college?

What does a telescope show about the Moon's surface? It seems to be made of materials much like volcanic areas on Earth. The jagged peaks, the dark rocks, the craters, all resemble western United States volcanic areas as viewed from an airplane. It will be useful to display samples of volcanic rock.

You may wish to try making model Moon craters. Bombard a soft clay or plaster of Paris surface with marbles or golf balls. Remove the projectiles and study how the "rock" formations built the rim of the model craters. Does dropping the projectiles from different angles change the shape of the crater? Recent Russian observations suggest volcanic activity as a source of mountain building on the Moon.

While smaller craters are probably the result of meteor impact, a very large crater may have been formed where material was ripped out by gravitational pull from a larger passing body in space. What is your opinion of Darwin's theory? Why is there disagreement? (There is no way to test it directly, as yet.)

Moon from the ocean. What can a map teach us? In what way does the Pacific appear different from other oceans? If your maps show ocean depths, can you find a reason that Darwin suspected the Pacific area of having provided material for the Moon? You may wish to try making and comparing cutouts of oceans to see why the area of the Pacific Ocean is large enough to have suggested the theory to Darwin. Why should you use a globe instead of a flat map to give you the ocean

Children examine inferences on which a theory is built and realize that every theory must be tested by evidence.

Equipment and Materials

. . . rulers
. . . paper disks to represent Moon
. . . volcanic rock samples
. . . soft clay or plaster of Paris mixture
. . . marbles
. . . golf balls

Equipment and Materials

. . . wall maps
. . . globe

Additional investigations reinforce the concepts of inertia of rest and inertia of motion.

Equipment and Materials

- . . . marbles
- . . . sheet of paper
- . . . pencil
- . . . tennis ball
- . . . string

Demonstrating the Laws of Inertia. Roll a marble toward the center of a table. Children can see that although the marble moves very easily, when it comes to rest, it stays at rest. Why? (Law of Inertia.) If you blow hard enough on the marble, will it move? Why? (An unbalanced force is acting.) Did the marble keep moving after you stopped blowing?

How could you use a piece of paper and a pencil to demonstrate inertia of rest? Place the paper on a flat, smooth surface. Lay the pencil on top. How can you remove the paper without moving the pencil? (By a short, quick jerk.) Can you state the law that explains this?

Tie a string around a soft ball, such as a tennis ball. What will happen if you swing the ball around your head and let go? Why does it fly off in a straight line instead of in a curved orbit? What law does this illustrate? (Inertia of Motion.) Why don't space capsules fly off straight into space? The Law of Gravitation is operating. Also their retro-rockets and other navigational devices make use of the Laws of Motion to keep them on a carefully computed course.

Extending the Concept

"On and on in a straight line." Encourage a child to practice rotating a marble in a saucer. Observe the motion of the marble as it gathers speed and flies out. What is the meaning of the word *tangent?* (Any line that can be drawn through one point on the circumference of a circle.) Rotate a ball tied to a string over your head and allow it to fly off in a safe direction. Do both marble and ball continue in a straight line?

Suggest looking up terms such as *arc, trajectory,* and *projectile.* By using colored chalk sketches, children may wish to present "chalk talks" to the class illustrating their understanding of the Law of Inertia.

Coasting in space. Coasting on a bicycle or on a sled or skis is a familiar experience to many children. Encourage individuals or teams to invent ways to show how coasting may occur in space. A simple illustration involves pushing a tennis ball off the edge of the table. Stand to the side and observe how the ball drops almost straight down. Repeat, giving the ball a shove which makes it travel in a curved arc as it falls. Relate this activity to the speed of an orbiting capsule around the Earth.

Returning astronauts to Earth. Some children may know of NASA projects for returning astronauts to Earth. These projects include the Dyna-soar, the Paraglide, and the Rogallo wing. Information collected on such projects may be better understood by drawing comparisons with the familiar paper dart or with some aspects of kite flying.

(*Text pages 110–111*)

Reviewing the Concept

Before You Go On. A. 1. b 2. b 3. b 4. a

Using What You Know. Its weight would be $\frac{1}{6}$ of its weight on Earth because gravitation is less on the Moon; its mass and inertia would remain the same.

Section 4: YOU ARE IN ORBIT

(Text pages 111–118)

Children gain understanding of the origin of the solar system and the shape of the orbit of all bodies moving in space.

SUBCONCEPT

Inertia and gravitation affect the path of bodies traveling in space.

Introducing the Concept

Processes emphasized

Model building
Observation
Hypothesizing
Theorizing
Library research
Reporting

Are you sitting still now? Are you really not moving? Could you sit still and be traveling 66,600 miles in one hour? This is really how fast you are moving around the Sun as a passenger on Space Ship Earth. How many miles do you travel in one year? (66,600 miles × 24 hours × 365¼ days = 584 million miles.) But this is not all. You are also spinning around once every 24 hours. Depending on where you live on the Earth (because it is shaped like a ball), you will spin through something like 20,000 miles every day. Can you demonstrate rotation and revolution, the Earth's two motions as it travels?

From what you have learned:

Why do you suppose the solar system looks like a pancake? How do Newton's laws explain Earth's motion?

Children should now start reading the textbook section, but you may prefer to develop the text concurrently with the suggested activities.

Developing the Concept

The masses of the Sun and the planets differ; hence, their gravitational pulls differ.

Equipment and Materials

. . . construction paper
. . . scissors

The sizes of the Sun and the planets. Select a wall space where the children can measure off about 9 feet (108″) to represent the diameter of the Sun (864,000 miles). Let them cut out a 1″ circle to represent the Earth. In review ask: Which would have the greater gravitational pull, the Earth or the Sun? Why? (The Sun's mass is much greater than Earth's; the Sun's pull will be greater.)

Children may cut out a $\frac{3}{8}''$ circle to represent Mercury, a $\frac{1}{2}''$ circle to represent Mars and Pluto, a 4″ circle for Uranus and Neptune, a $9\frac{1}{2}''$ circle for Saturn, an 11″ circle for Jupiter, and an 8″ circle for Venus. (These are approximate measurements of diameter on a scale of 1″ = 8,000 miles.) How is their gravitational pull related to their sizes and hence to their masses? If time permits, arrange the cutout models as a chart or mobile to represent the differences in gravitational force.

Children infer that Newton's Laws of Gravitation and Motion help explain the origin of the solar system.

Equipment and Materials

. . . hand mirror or aluminum foil
. . . teakettle
. . . marbles
. . . bowl

A theory about the solar system. After the children have read "A Cloud of Gas" (text page 113), they may be able, with help from earlier sections in this unit, to draw valid inferences. For example: Why do the Earth and the other planets orbit the Sun? (Sun's greater gravitational attraction.) Why don't all the planets fall into the Sun? (All the planets are moving, but being pulled by the Sun's gravitation; i.e., the Sun's gravitation is the unbalanced force that acts on the inertial straight-line motion of the planets.) These same forces existed in the cloud of gas. Review, if necessary, activities suggested in the previous section.

The text states: "As this cloud shrank, masses of the cloud began to come together. . . . Each protoplanet got still smaller" (text page 114);

outlines? Just south of the United States lies a great gulf and a sea ringed with islands. Some think this sea represents another hole where material was torn or blasted from Earth. Some think the islands are remnants of a huge crater rim. Can you find this sea (the Caribbean) and imagine a great piece of Earth's surface ripped out, much as a chunk of tread is ripped out of an old tire as it spins along?

If men can bring back a piece of Moon rock, how will scientists use it to test George Darwin's theory? (They will compare it with the rock from the beds of the Pacific and the Caribbean. If the specimens are identical, George Darwin's theory will have passed a fine test.)

Children begin to sense some relationships between distances and time in space travel.

What is the Moon's orbit like? How far is a thousand miles? With the aid of maps (wall maps of the United States or the Western Hemisphere are useful), encourage children to relate distances in their experience to 1,000-mile distances on the map, say Chicago to New York, Denver to Los Angeles. Can you imagine 240 such distances laid end to end? If it takes $1\frac{1}{2}$ hours nonstop to fly by jet the thousand-mile strip between Chicago and New York, how long would it take you to jet to the Moon? (Approximately 360 hours or 15 days nonstop.) Using a scale of 1″ per 1,000 miles, encourage children to decide the appropriate size of a Moon (2″ across) and an Earth (8″ across) cutout. How far apart should they be pinned up? (20 feet.) Review the shape of the orbit of the Moon. How is the orbit of the Moon related to Newton's Laws?

Rotation and revolution differ for different bodies in space.

Why do we see only one side of the Moon? In review of *rotation* and *revolution*, let several children act out these motions. Can one child act out both motions at the same time?

Equipment and Materials

See text page 123; also the Teacher's Manual for *Classroom Laboratory 5.*

We see only one side of the Moon. Does the Moon revolve but not rotate? Ask for two volunteers to demonstrate, one as Moon, one as Earth, but caution the "Moon" to revolve (circle) so that "Earth" always sees his face. Ask the "Moon": Did you revolve? Did you rotate? The clue to an affirmative answer lies in whether he saw all four sides of the room as he revolved around his partner. If the concept is still not clear, ask the child slowly to make one complete turn in place. Did you see all four sides of the room? Did you rotate? Why must the Moon rotate just once, when it revolves around the Earth once? This preliminary dramatization sets the stage for modeling a planetarium (text page 123).

Extending the Concept

What is a planetarium? Children who have not had opportunity to visit a large planetarium may enjoy writing to the nearest one for free or inexpensive printed information. The following partial list may be of assistance:

Adler, Chicago, Ill.
Buhl, Pittsburgh, Pa.
Fels, Philadelphia, Pa.
Griffith, Los Angeles, Calif.
Hayden, New York, N.Y.
Morehead, Chapel Hill, N.C.
Morrison, San Francisco, Calif.

Earth craters and Moon craters. To help children visualize the topography of the Moon, encourage them to make a scale model. A large, flat piece of plywood or a cafeteria tray can serve as a base. Use modeling clay or make a paste of flour, water, and salt or of detergent powder and water. Using recent encyclopedia or *National Geographic* pictures for reference, the children will enjoy molding to approximate scale the major features of the Moon's surface. Toothpicks carrying tags naming each feature could be appropriately placed.

Equipment and Materials

. . . tray or plywood sheet
. . . modeling clay
. . . toothpicks
. . . paper tags

(*Text page 124*)

Reviewing the Concept

Before You Go On. A. 1. While the Earth was being shaped, a large mass of it tore loose to form the Moon. 2. More evidence is needed. 3. An elliptical orbit around the Earth.

Using What You Know. 1. An ellipse. 2. Theory—a reasonable explanation that satisfies many observations that have been made; law—a theory that has stood the test of many investigations over a long time.

(*Text pages 125–128*)

SUBCONCEPT

Exploration of the Moon depends upon understanding how the position and motion of bodies in space are affected by gravitation and inertial motion.

Processes emphasized

Library research
Consulting with "experts"
Investigation
Observation
Model building
Inventing
Measurement
Analysis of reports (newspapers and science fiction)

SECTION 6: MAN ON THE MOON?

Children relate and apply learnings of the previous sections to a hypothetical trip to the Moon. They learn that man's understanding of the effect of action-reaction and of gravitation will enable him to travel through space, land on the Moon, and return.

Introducing the Concept

Suppose that you are an astronaut who has been selected to make a trip to the Moon. Describe your spacecraft. What will you wear? What do you need to carry with you? How will it feel to take off? To land?

In advance of introducing this section you may wish to encourage children to collect information from current television programs and from magazines, both of which should offer a wealth of background. Children will delight in gathering illustrations and printed articles and organizing them into an exhibit. Some children may have made rocket models which would add interest. Others might wish to bring science juveniles on space and the Moon from their home libraries. Initiate reading of the text with these questions:

What scientific laws will astronauts use to control the course of their mooncraft? What special protection will they need to explore the Moon? Why will moving about on the Moon differ greatly from moving about on Earth?

Developing the Concept

Using the Laws of Motion. From your reading of the section, can you point out the applications of Newton's action-reaction principle in a

Children relate their knowledge of the Laws of Motion to a Moon launch and landing.

rocket launch? What is the action? The reaction? Where does the energy come from? Can you decide, if each rocket engine produced $\frac{3}{4}$ million lbs. of thrust or push, what would be the total thrust? By changing the fraction, the children can make up additional problems with which to challenge one another or the total group. This procedure will not only offer a review of fractions but will also underline the importance of mathematics in science.

At a speed of 25,000 miles per hour, rocket engines are cut loose and the Moon capsule coasts. What principle keeps the capsule moving all the way to the Moon? (The Law of Inertia.)

Before landing on the Moon, how do the astronauts apply the action-reaction principle? (Reverse rockets to slow down the speed of landing.) How do retro-rockets resemble the rudder of a boat? What principle must astronauts apply in leaving the Moon? (Action-reaction.) Why? (To escape from the Moon's gravitation.)

The flight of a space capsule to the Moon is affected by gravitation.

Gravitation and space travel. The text states that a rocket must develop a speed of 25,000 miles per hour to escape from an Earth orbit. Why would a space capsule go into orbit at a lower speed? (There would not be enough thrust, unbalanced force, to overcome Earth's gravitation.) Is the Earth's gravitation the same 50,000 miles in space as it is at the Earth's surface? Although the text does not discuss the relationship between gravitation and distance, many children will be able to deduce that the farther a capsule is from the Earth, the less the Earth's gravitational pull. This inference also helps children see why the space capsule speeds up as it approaches the Moon and experiences the Moon's gravitational pull.

Why will less fuel be needed to leave the Moon? (Less gravitational pull to overcome.) How is this an advantage? (Less fuel needs to be carried. The more fuel that has to be carried for a return flight, the greater the thrust that must be developed on takeoff from Earth.)

Why will an astronaut be able to move easily on the Moon even if his Moon suit weighs 200 pounds?

Children begin to see how astronauts will be able to meet special conditions on the Moon.

Conditions on the Moon. Why must Moon explorers have special suits? Why do the suits have a heater and an air conditioner? (There is no atmosphere on the Moon.) Can you think of a way to show how the atmosphere protects the Earth from the great heat that exists on the lighted side of the Moon and the extreme cold on the dark side? Some children may be challenged to devise a demonstration with an unshaded light bulb and one enclosed in an inflated plastic bag. Why does the astronaut's suit have a radio? Some children will be able to infer that radio signals travel through space, and that sounds must be transmitted by molecules of matter. Why must the astronauts carry their own food? What else do you think would be useful? (Water, air, equipment for collecting rocks and other surface samples, for measuring temperature, for taking readings of radioactivity.)

Extending the Concept

Equipment and Materials

- . . . 10 pencils in rubber band
- . . . map roll
- . . . paper cup
- . . . cutouts of skyscrapers
- . . . picture of Washington monument
- . . . cutouts of autos

Saturn rocket to the Moon. What does the Moon-shot vehicle look like? Can you think of a way to show it? One child used a mailing tube capped with a paper cone sitting on a vertical cluster of ten pencils. Can you think of a way to show the huge size of the Saturn rocket? A picture of the Washington Monument or of an eighteen-story building would give some idea. How does it feel to be at the top of a fifteen- to twenty-story building? Some children may have had the experience. What is the measure of Earth's pull on the Saturn rocket? (Six million lbs.) How much is a million pounds? How much does your car weigh? Cars average about two- to three-thousand lbs. If you had a scale big enough, how many autos would you need to pile on it to compare with the Saturn?

The LEM and other exploratory modules. These are probably more familiar to children than to most adults. Encourage children with special interest in these new space developments to extend and plan an illustrated report.

Only one Moon? From science in the news many children are already aware that other planets have moons. Encourage them to develop a chart or exhibit illustrating the moons of the planets in the solar system:

Mercury – 0
Venus – 0
Earth – 1
Mars – 2
Saturn – 9
Uranus – 5
Neptune – 2
Pluto – 0
Jupiter – 12

Interested students may discover, through reading in an encyclopedia, the sizes of the moons and relate these sizes to the sizes of the planets they orbit.

How true is science fiction? If possible, secure Jules Verne's old classic, *A Trip to the Moon*, and read some passages to the children. The sections which describe the rocket launched from Florida may be of interest and relevance. Let the children discuss what ideas were proved right after many tests. Which parts of the book proved fanciful? The discussion could lead to an interesting evaluation of science fiction, past and present; even to television programs, comic strips, and newspaper articles.

(*Text page 128*)

Reviewing the Concept

Before You Go On. A. Child's sentences.

Using What You Know. 1. Moon has less gravitational pull and space capsule has less mass attached, as empty rocket shells have been discarded. 2. At this speed, it overcomes the Earth's gravitational pull; below this speed it is pulled back to Earth.

(Text pages 129–137)

CONCEPTUAL SCHEME

When energy changes from one form to another, the total amount of energy remains unchanged.

UNIT CONCEPT

Energy must be applied to produce an unbalanced force, resulting in motion or change of motion.

Section 7: THE MAIN CONCEPT: EARTH IN ORBIT

Children review the concepts of universal gravitation, inertia of motion, and action-reaction. They fix the concepts that help explain how the Earth is held in orbit just as are other bodies in the universe. The same concepts help explain the motion of rockets and artificial satellites.

CONCEPT SUMMARY

You may wish to have the children read the entire section before you engage in activities to summarize and fix the concept of this unit, or you may prefer to engage in concurrent reading and discussion. Your choice may depend on your evaluation of the readiness with which the children have grasped the essential subconcepts of each section as it was studied.

What holds the stars and planets in space?

You may wish to begin by having some helpers reproduce the demonstration suggested in the text. The stirring motion of the finger sets the pepper specks whirling. Of what is this a model? What invisible force holds planets, stars, and galaxies in order as they whirl around and around like the grains of pepper? What laws enable men to set a great rocket carefully and exactly on course to the Moon? Suppose you become a space explorer. What laws of science would you depend on to launch you from Earth and to bring you home again?

What is the Milky Way Galaxy like?

Look across the room. Do you see everyone in it? (No, especially if the room is crowded.) In the same way it is impossible to look through your galaxy and see all the stars in it. Whichever way you look, nearby planets or stars cut off your view of distant stars. In great areas of the Milky Way, clouds of fine dust block the view. Most of what you know about your galaxy is based on studies of other galaxies. For example, imagine you are taken blindfolded to a strange house. You are placed in a room and your blindfold is removed. Your room has a window looking out on neighboring houses. You make deductions about the house in which you find yourself from the houses seen from your window.

A galaxy has been compared in shape to a filled cookie. What else can you find out about galaxies? Your school librarian may suggest references on galaxies. For helpful suggestions, see Chapter 6, "Using Reference Materials" in *Science Education for Elementary School Teachers.*

Equipment and Materials

. . . unshielded light
. . . tissue paper

In addition to compiling and pooling information on galaxies, it may be useful for children to approximate an analogy for the beautiful Andromeda nebula or galaxy. Seen through binoculars on a crisp autumn night, the nebula looks like a hazy patch of light instead of the pinprick light of a single star. An unshielded light covered by tissue paper produces a patchy light. Is our solar system at the hub or center of the Milky Way Galaxy? If not, where is it?

Since this unit has been concerned with the motion of bodies on Earth and in space, a summary of the concepts should review a few fundamental ideas. The following suggestions for discussion should help focus the child's attention on certain now familiar phenomena.

What forces act on an object at rest?

The text (page 131) states: "Every body in the universe attracts every other body." Here is a box resting on the table. Why is it not moving? (The Earth's gravitation is pulling on its mass and the mass of the box is pulling on the Earth. The forces are balanced.) This illustrates Newton's Law of Gravitation. Now push against the box, but not hard enough to move it. Can you feel it pushing against you? Again there are balanced forces working opposite each other. Which of Newton's Laws is illustrated? (Inertia of Rest.) A capsule is on its launching pad during countdown. Can you explain in terms of gravitation and inertia?

How is an object set in motion?

Push against the box on the table again but this time enough to move it. Why did it move? (The energy put into pushing creates an additional force—an unbalanced force—that sets the box in motion. The box continues to move as long as this unbalanced force is exerted.) The countdown on a launching pad reaches the blast-off signal and the space rocket takes off. Why? (The energy in the fuel creates an unbalanced force that is greater than the balanced gravitational forces.)

How is an unbalanced force created?

Where does the rocket get its force? (From the energy in rapidly burning fuel.) Which of Newton's Laws is illustrated? (Action-reaction.) The blast of burning gases from the rocket's tail pipes creates a directly opposite reaction that sends the rocket off against the pull of gravitation. An unbalanced force has been added. A perceptive child may correctly infer that balanced forces are examples of action and reaction; the action of the Earth's gravitation on a stationary object is exactly balanced by the reaction of the object's pull against the Earth. Action and reaction, *when energy is supplied*, will create an unbalanced force that acts against inertia, the situation that exists before energy is supplied.

How is the motion of an object stopped?

Why did the box you pushed stop moving? (The friction of the table top became an unbalanced force and stopped the motion when the energy to keep the box moving was withdrawn.) Why does a Fourth of July rocket fall back to Earth? As soon as its energy is used up, the friction of air and gravitation slow it down. Gravitation is no longer overcome; it is the unbalanced force that pulls the rocket back to Earth. Why does a ball stop or change direction when it hits a wall? An unbalanced force acts against its forward motion. How does an astronaut use rockets on his capsule to slow it down as he approaches the Moon or the Earth? He uses burning fuel (action-reaction) and in this way creates an unbalanced force that acts against the forward motion of the capsule.

Why does a capsule keep moving in space?

Suppose there were nothing that could stop an object moving. What would happen? (The object would keep moving in a straight line.) Of what would this be an example? (Inertia of motion.) Where might such conditions exist? (In space where there is no atmospheric drag.) Do objects in space travel in a straight line? (No.) Why not? (Gravitation acts on all bodies in space; gravitation is an unbalanced force that changes the direction of all bodies so that they move in a curve. A space ship depends for its motion on the energy applied to it.)

Challenge the children to cite other illustrations from their own experience that will help fix in mind the concepts that are inherent in Newton's Law of Universal Gravitation and in his Laws of Motion.

(Text pages 133–137)

FIXING THE MAIN CONCEPTS

A. 1. $\frac{1}{6}$ of your weight on Earth. 2. Unchanged. 3. It becomes less. 4. Nothing. 5. In front; objects in motion continue in motion in a straight line (Newton's Law of Inertia). 6. Spray the extinguisher in direction opposite to that in which he wishes to go (Newton's Law of Action-Reaction).

B. Consult glossary.

C. 1. d 2. a 3. b 4. a

(Text pages 138–143)

A NEW VIEW OF MATTER AND ENERGY

CONCEPT RELATIONSHIPS

Matter can be changed into energy; however, the total amount of matter and energy in the universe remains the same.

Children, as they recall the important concepts of the first three units, begin to see that the continual transformations of matter and energy, and their interchange, help explain the changes in the Earth and in the universe of which it is a part. Children have an opportunity to bring together what they have learned as they engage in further concept-seeking and concept-forming.

TEACHING SUGGESTIONS

The purpose of the three "New View" sections is to enable children to reconsider what they have learned in earlier units and to draw relationships between concepts they have been forming. As they read the section, encourage them to pause at each concept stated in italics (as repeated also in the margin) and sort out the evidence they have that illustrates and supports them. To generate thinking and discussion, you may wish to devise situations or questions modeled on those that follow:

Objects and events can be grouped or classified.

"The world is so full of a number of things." How many things can you see in the classroom? How, for example, do you sort or group the science materials and equipment you use? Would you keep rocks, microscopes, bottles, sand, acids, bases, and salts all mixed up together? A trip to a science museum would show children how scientists sort out and label objects they have studied. Some of the children may describe exhibits they have seen at such a museum or the ways a hobbyist or collector arranges the items in his collection. When you studied rocks, why did you classify them in three groups? What other things have you classified this year? Children will realize more fully the importance of structure and properties of objects as aids to classifying them.

All matter is made up of elements. All matter is made up of atoms. All matter is made up of particles.

You have learned that objects can be grouped by their structure. What are compounds built of? Elements? Atoms? How does a knowledge of atomic structure enable us to describe all the matter of the Earth which we studied in the first two units? What changes in the form of matter can you name? (Solids to liquids to gases; elements to compounds; etc.) Is matter gained or lost in a physical change? In a chemical change? Does any of the matter of the Earth ever stay the same, without any change?

In chemical change, matter is not destroyed, only changed from one form to another.

Can you name two places where a small amount of matter is being changed to energy? (In the Sun by fusion and in Earth's radioactive rock by fission.) How is this change of matter to energy related to changes in the Earth? To your own lives? Children recall that the heat energy that pushes up mountains and causes volcanoes to erupt results from the changing of nuclei of radioactive atoms into energy. They also recall that the one two-millionths of the Sun's energy is just the right amount for life to exist on Earth. They realize that there are orderly relationships between matter and energy.

Matter can be changed to energy. The total amount of matter and energy in the universe remains the same.

Why does an object at rest remain at rest? Why does an object in motion in space remain in motion? (The forces acting on it are balanced.) How can you set an object in motion? How can you speed up the motion of an object or stop it? (Apply energy.) What is the name for the force the energy supplies? (Unbalanced force.) Think of ways you could move an object by using different kinds of energy. Children with facility in drawing might diagram changing stored chemical energy to electrical energy to mechanical energy, heat energy to mechanical energy, mechanical energy to electrical energy, as well as other forms and combinations of energy changes. When energy is released, what usually happens? (Motion takes place in the direction the unbalanced force is applied.)

An object at rest remains at rest and an object in motion remains in motion unless acted on by an unbalanced force.

What would happen if the force of gravitation were suddenly to stop working? What would happen to you? To the Moon? To the Sun? To all bodies in the universe? In what direction would they move, according to Newton's Laws of Motion? How does gravitation affect objects in motion? If the speed of an astronaut's capsule becomes slower, can you explain what happens, using Newton's Laws of Gravitation and of Motion?

All objects attract one another by the force of gravitation.

What do the words *action* and *reaction* refer to? (Forces.) If the action is to the east, in what direction must the reaction be? (West.) How is the principle of action-reaction used by an astronaut?

Every action has an equal and opposite reaction.

Matter—energy—motion. Can you think of one without the other? Can there be matter without any motion anywhere? Can there be energy without matter? Any motion without energy? How have your ideas about matter and energy changed as a result of your study this year? As your textbook says: "We all live in the universe. We ought to try to understand it." That is, we need to discover how the universe works.

UNIT THREE

THE EARTH IN ORBIT

Look at the Earth.

Oceans and continents. Mountains, lakes, rivers, and deserts. Farmlands and cities.

This is what astronauts may see behind them as they head out into space for the Moon. For the first time men are leaving the Earth. Why do they go? What do they hope to find? How can they leave the Earth? A good way to begin is to see what holds astronauts—and everyone else—to Earth.

1. The Pull of the Earth

Toss a ball up a few feet, and down it comes. Throw the ball up as hard and as high as you can, but down it comes. Hit it with a bat, harder and higher. It comes down. What goes up, comes back down, it seems. People have known this fact for thousands of years.

"What goes up must come down," we used to say. Now we are not so sure.

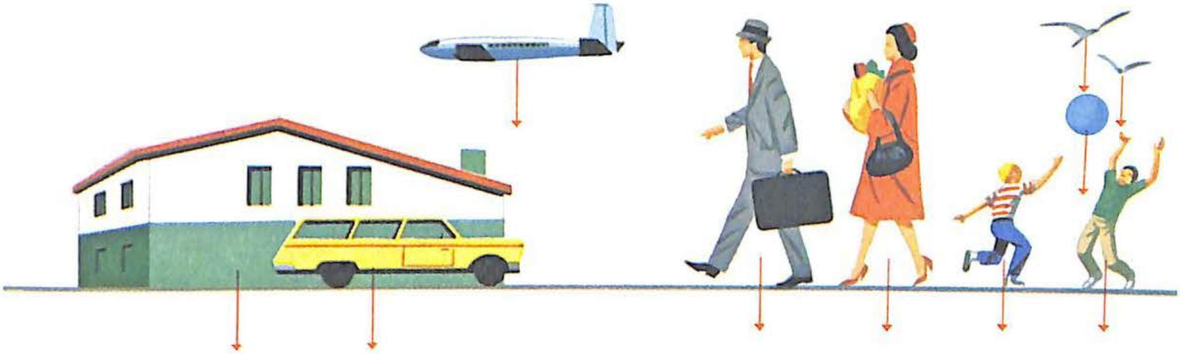
Put a man on the tip of a huge rocket. With a terrific roar the rocket throws the man up—into space.

What goes up does *not* always come down. The old saying is out of date. For we are beginning to learn how to travel away from our Earth and out into space.

How we are learning to do this is an exciting story. Let's start by looking at whatever it is that makes most things come back to the Earth. What is it that holds us to the Earth?

About 300 years ago a young man named Isaac Newton noticed an apple fall to the ground, so the story goes. See the picture marked with a square. ■ Of course he had seen apples fall from trees before. But this apple started him thinking about something. Why do apples, sticks, leaves, stones—all things—behave the same way when they fall?

■



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Newton's explanation seems simple. You will see later, however, that it had an astonishing result. He said that there was a **force,** a push or pull, acting on the apple. It pulled the apple toward the center of the Earth. He called this force the force of **gravitation** (grav′ə·tā′shən).

The force of gravitation does not act on apples only. All objects, including you, are pulled or attracted to the Earth by the force of gravitation.● This is why things are held to the Earth. This is why things fall. They are pulled to Earth.

We often use the word **gravity** when we talk of the pull of gravitation on Earth. You will hear people saying that it is the pull of gravity which holds things to the Earth. They are speaking of the force of gravitation, however. Gravity is one sort of gravitation.

It is the force of gravitation that prevents you from floating off the Earth into space like a runaway toy balloon.▲ Clearly, it is an important force. How big is this force that holds you to the Earth? It is easy to find out. Just step on a scale.

Whatever you happen to weigh is the amount of the force holding you to the Earth. If you weigh 100 pounds, you are being pulled to Earth by a gravitational force of 100 pounds. Weigh this book and you will find that the pull of gravitation attracting it to Earth is about $1\frac{1}{2}$ pounds. A rocket that weighs 100 tons is held to Earth by a gravitational force of 100 tons. The rocket engines must overcome that force of 100 tons.

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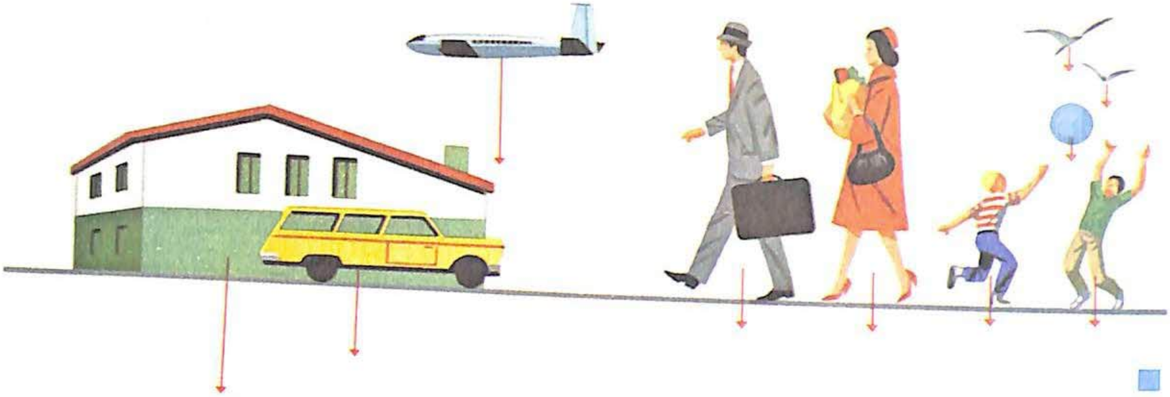
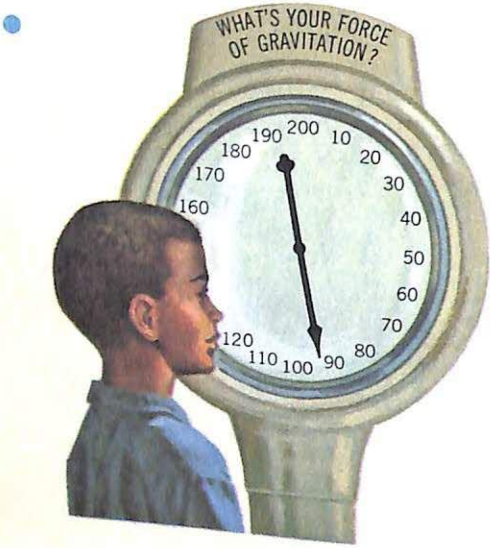


Weight is a measure of the force of gravitation on an object. ■ Instead of asking, "How much do you weigh?" you could say, "What's the force of gravitation on you?" A scale could be called a force-of-gravitation meter. It shows how much force of gravitation is pulling on an object. ● To understand more about how a scale acts as a force-of-gravitation meter, do the investigation on the opposite page.



The Pull of the Moon

Now let's leave the Earth for a while. Let's see what happens to gravitation and weight somewhere else.

What happens to gravitation and weight on the Moon?

Suppose that an astronaut who weighs 180 pounds on Earth lands on the Moon. How much would he weigh there? He might be a little clumsy about getting on a scale, because of a strange feeling of lightness. But once on the scale he would see why he felt light. The scale would show his weight to be 30 pounds!

This is quite a change, compared with the astronaut's weight on Earth. How much of a change is it?

weight on Moon = 30 pounds
weight on Earth = 180 pounds

How many times as much does the astronaut weigh on the Earth as on the Moon?

$$180 = 6 \times 30$$

AN INVESTIGATION into the Pull on an Object

Needed: a spring balance, an equal-arm balance, a box of weights, an empty pint milk carton, sand, string, a spoon

Set the carton on the left-hand pan of the equal-arm balance, and set a 250-gram weight on the right-hand pan. With the spoon, put enough sand in the carton to make it balance the 250-gram weight. ■

Now take the 250-gram weight off the balance. What happens to the carton of sand? ● It goes down. What moves it down? Some force must move it, for an object does not move from rest unless it is pushed or pulled by a force. The force which pulls the sand down is the force of gravitation.

With how much force does gravitation act on the sand? It acts with 250 grams of force. Can you tell why?

To act against this 250-gram pull of gravitation, how much force would you have to use? Put strings through the side of the carton. Lift the carton of sand with the spring balance. ▲ What does the spring balance read? ◆

To act against a pull of gravitation of 250 grams, an opposite pull of 250 grams is necessary.

Additional Investigation: Determine what force would be needed to act against a gravitational pull of 750 grams.

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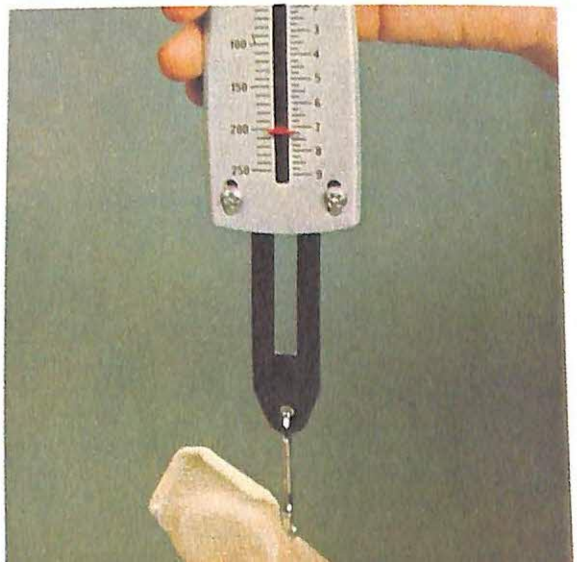

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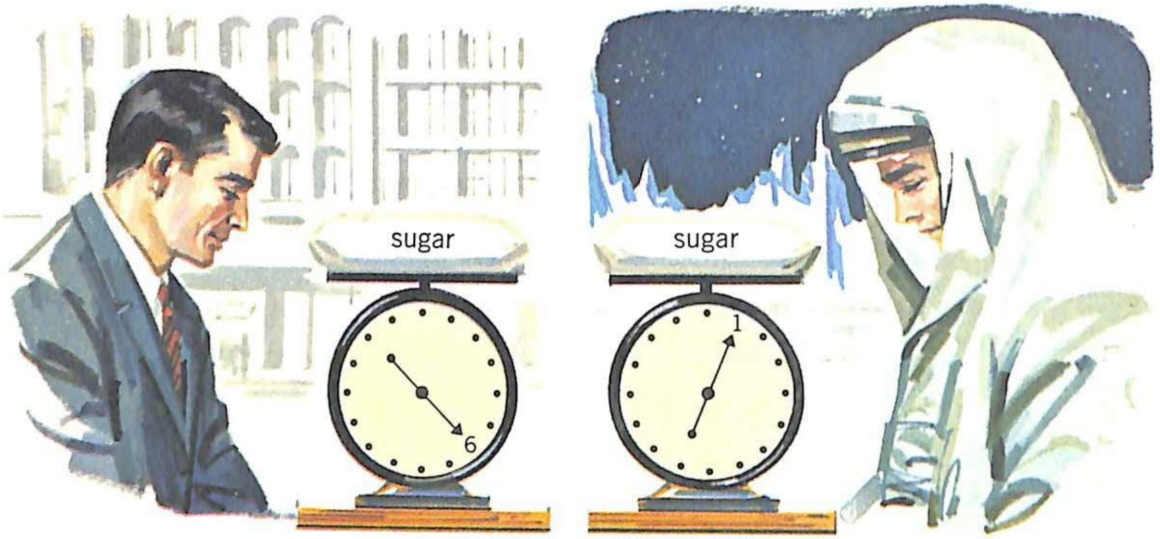


The astronaut weighs six times as much on the Earth as on the Moon. The astronaut's weight on the Moon is $\frac{1}{6}$ of his weight on the Earth.

At first, going to the Moon may look like a good way to lose weight without dieting. What has really happened? Has the astronaut changed? Not at all. He hasn't shrunk. The number of atoms and molecules in his body is about the same as on the Earth. The amount of matter that he is made of is called his **mass.** The astronaut's mass hasn't changed. The amount of matter his pressure suit is made of is its mass. The amount of mass in his pressure suit is the same on the Moon as on Earth. What has happened, then?

The astronaut's weight has changed because the gravitational pull on him has changed. The force of gravitation on the Moon is less than the force of gravitation on the Earth.

Weight and Mass

Remember what weight is? Weight is the gravitational pull on an object. If, somehow, the pull of gravitation changes, then the weight of the object changes. The mass of the object, the amount of matter it is made of, does not change.

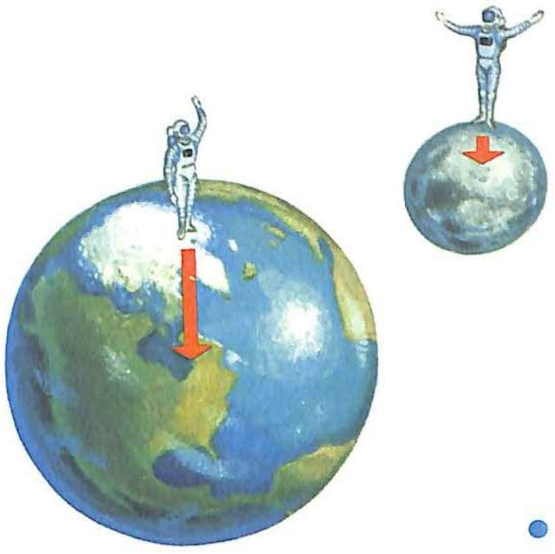
If a bag of sugar weighs 6 pounds on Earth, what will it weigh on the Moon? It will weigh 1 pound on the Moon, $\frac{1}{6}$ of its weight on the Earth.

There is just as much sugar in that bag when it is on the Moon as when it is on the Earth. We could make the same amount of candy from it, for instance, in either place. The mass of sugar in the bag has not changed. But the force of gravitation on the Moon is $\frac{1}{6}$ of the force of gravitation on Earth. So the Moon weight of the sugar is $\frac{1}{6}$ of the Earth weight.

Here on the Earth we usually talk as if weight and mass were the same thing. We use weight as a way of measuring mass. On the Earth this is very convenient. A mass of sugar that weighs 6 pounds in California will weigh 6 pounds in Oklahoma or Texas or Maine because the force of gravitation in each place is practically the same.

As long as we stay on Earth, using weight to measure mass works pretty well. Now, however, men are beginning to leave the Earth. Suddenly we realize that weight and mass are not the same thing! Away from the Earth, the force of gravitation changes.● As the pull of gravitation changes, weight changes, but the mass of an object does not change. The mass of any object stays the same anywhere in the universe—whether it is on Earth, on the Moon, in a spaceship, or on Mars.

Have you wondered why the pull of gravitation on the Moon is only $\frac{1}{6}$ of the pull on the Earth? Here is a reason. The Moon, you know, is a good deal smaller than the Earth. The Moon, all in all, has less mass than the Earth.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Since the Moon has much less mass than the Earth, it has much less gravitational force than the Earth. Which pair of astronauts in this illustration must be on the Moon?▲ Which pair must be in training on Earth?

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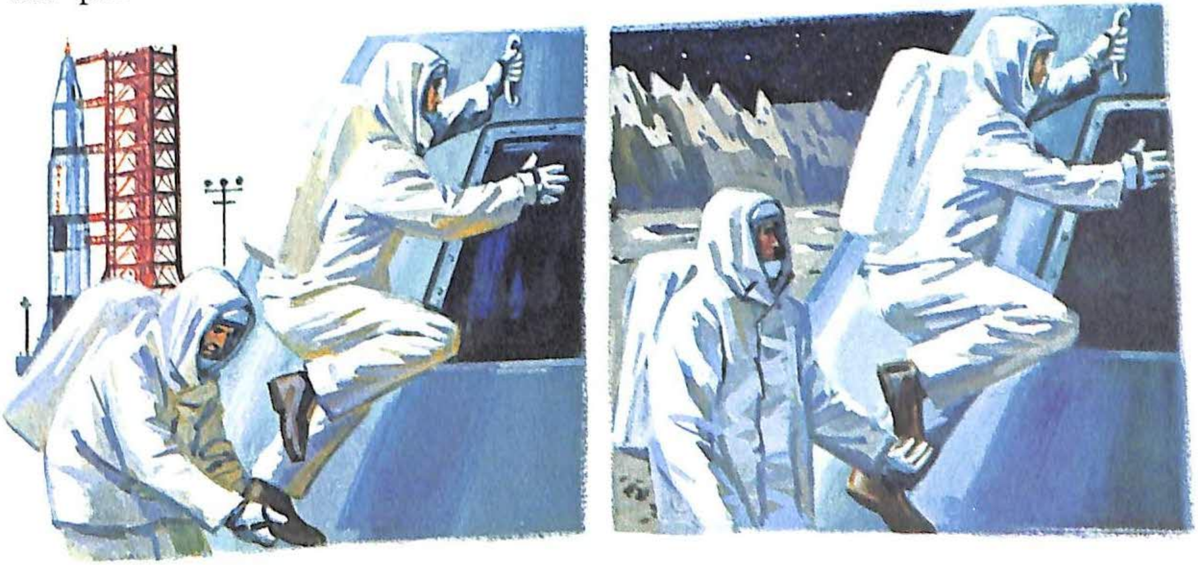


BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. All objects on the Earth are pulled to the Earth by

a. weight b. gravitation

2. An astronaut on the Moon will find that he has changed in

a. mass b. weight

3. An object's mass on the Moon, on Mars, and on the Earth would be

a. the same b. different

4. If a boy weighs 120 pounds on Earth, his weight on the Moon would be

a. 60 pounds b. 20 pounds

B. Write a paragraph or two on this topic: "My Weight on the Moon."

USING WHAT YOU KNOW

1. Imagine that in the year 2000 anyone can visit the Moon. You take the trip. What would your weight be on the Moon?

2. A planet far off in space is the same size as the Earth, but has about ten times the mass of the Earth. What would be the weight of an astronaut on this far-off planet who weighs 150 pounds on the Earth? Would his mass have changed?

ON YOUR OWN

Isaac Newton was 12 years old in 1654. What was his house like? his food? his clothing? What sort of boy was he? What was our own country like in those days?

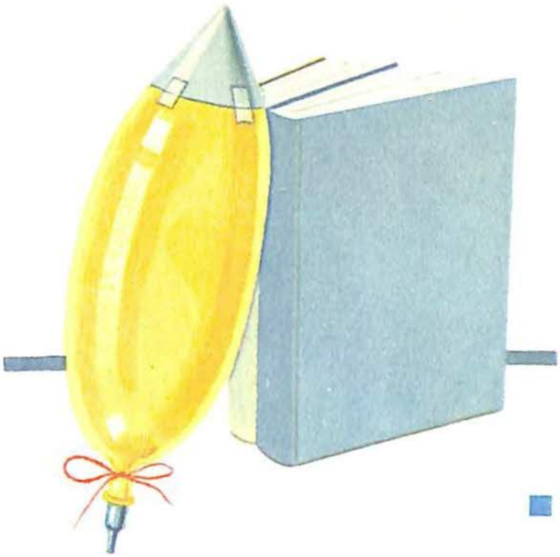
Where would you look for answers to these questions?

2. Man Off the Earth

Gravitation holds us tightly to the Earth. How can we get away, then?

A model will help us to see the answer. Take a sausage-shaped toy balloon. With a piece of string, tie the mouth of the balloon around a glass medicine dropper. Blow up the balloon and tie it with a bow knot. Fasten a paper cone "space capsule" on top, and you have a model rocket. ■

Prop up the model rocket against books as shown. Pull the string to loosen the knot. Air rushes out. "Blast off!" The blast of air gives the rocket a push called **thrust.** The force of the thrust lifts the rocket model off its pad, and it is on the way. Alas, it soon falls back to Earth. Why didn't the model rocket go on?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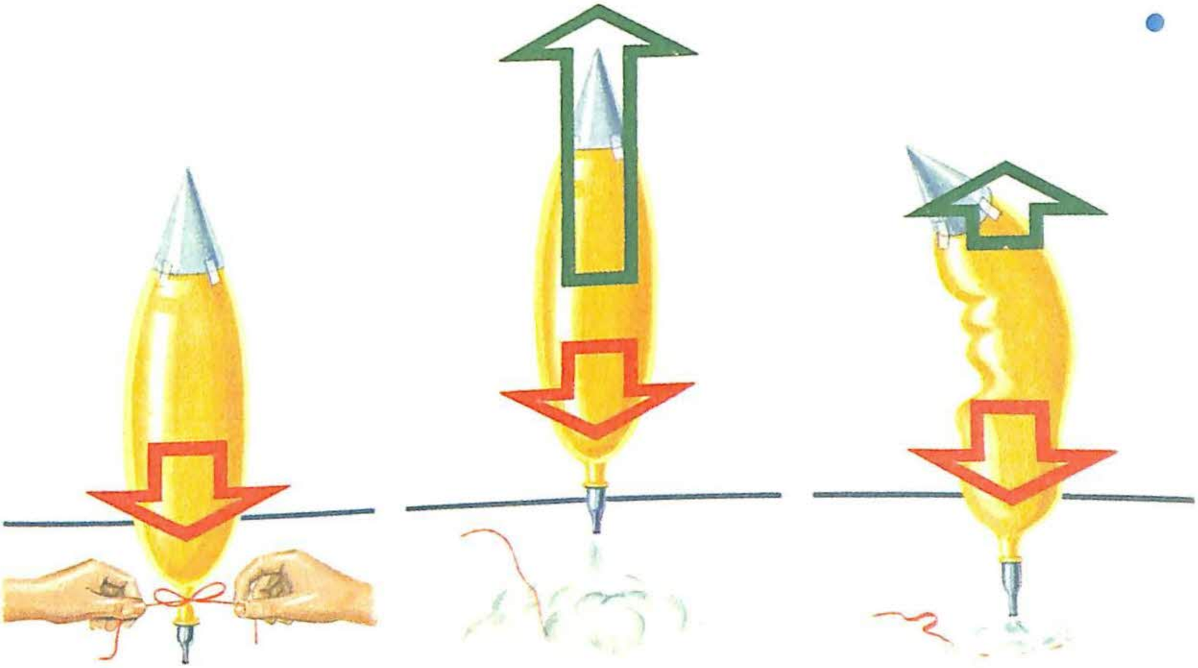
Why the Thrust Stopped

The thrust of the squirting air lifted the rocket from the ground. The pull of the Earth's gravitational force brought it back. ● The force of the thrust was greater than the force of gravitation and acted against it but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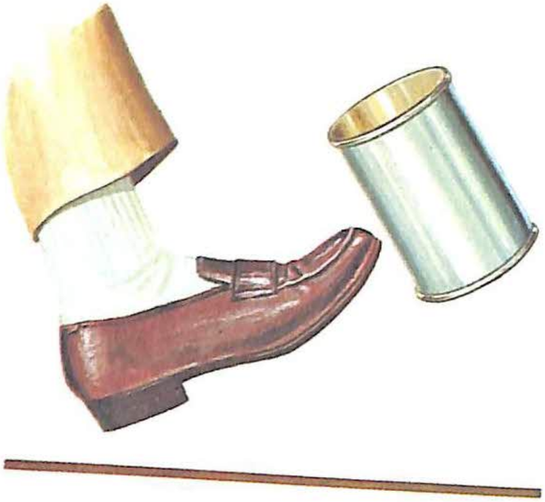

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not for long. There was not enough energy in the air leaving the balloon to keep it going for long.

There was not enough energy to keep the thrust going. As soon as the supply of energy ran out, the model fell back to Earth. Of course you could blow more energy into the balloon again, perhaps a little more than the first time. However, as you know, a balloon will hold just so much energy of this kind!

The energy in the model, like the energy in a real rocket, provides thrust. The force of the thrust is what lifts a rocket. To get something moving takes a force, a push or a pull.

Why must there be a force to get something moving?

Tin Cans and Rockets

A boy sees a tin can sitting on the ground. He can't resist it. He gives the can a kick, and off it goes. ■ Perhaps you have done the same thing.

An astronaut roars into space in the nose of a giant rocket. What has this to do with a tin can rolling along the ground? The moving rocket and the moving can are alike in an important way. Both move because a certain kind of force is at work. Let us see what that force is.

Think of a can at rest on the ground. Is any force acting on it? Yes, the force of gravitation is pulling the can down. Why doesn't the can move down then? Because the Earth is pushing up against the can. The force pulling down is balanced by a force pushing up. ● The can stays still, because a **balanced force** is acting.

The twins in the tug-of-war do not move. ▲ Their forces are opposite, and they balance. Now, if another boy helps to pull on one side, then they all move. ◆ An **unbalanced force** has been added. The unbalanced force is the one that makes the boys move. Balanced forces acting on opposite sides of an object cannot move it.

Let's look at the tin can again. The can at rest has balanced forces acting

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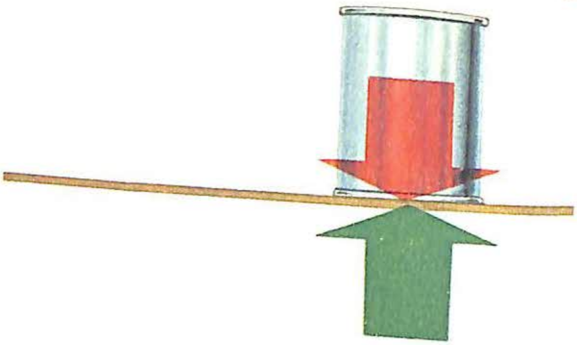

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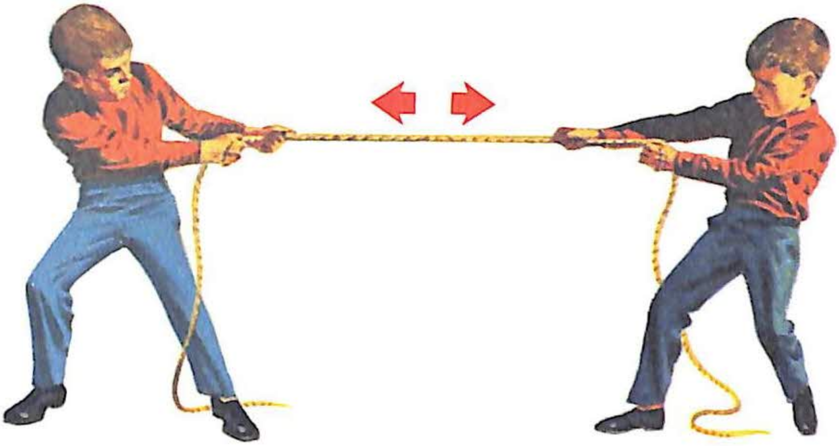

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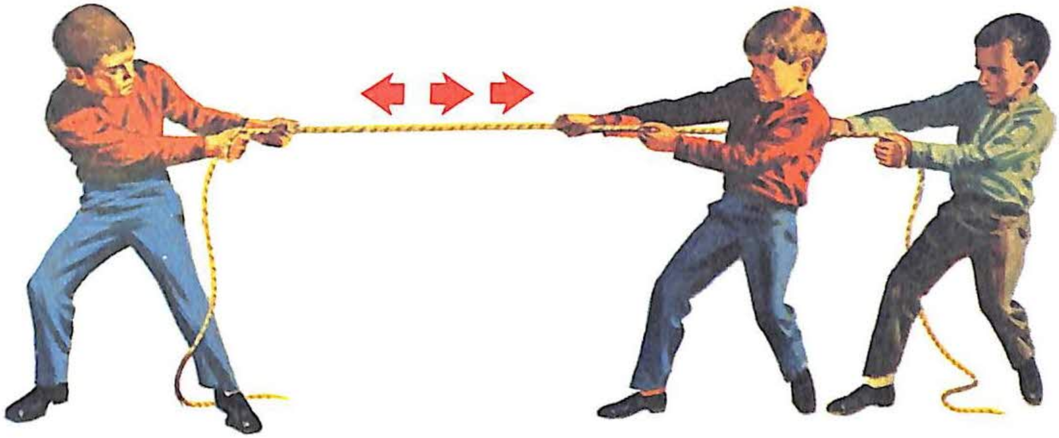

on it. The kick comes along—and adds an unbalanced force.★ Off goes the can. An unbalanced force is what makes things go. We might kick the can into space if we had a big enough unbalanced force!

The unbalanced force is what makes a rocket go, too. Its engine has enough energy to overcome the Earth's gravitation and to bore through the Earth's atmosphere into space. What a tremendous kick the unbalanced force of the rocket engine gives!

How is such a tremendous force produced?

Build the jet engine on the next page. It will help you to see how a rocket engine works.

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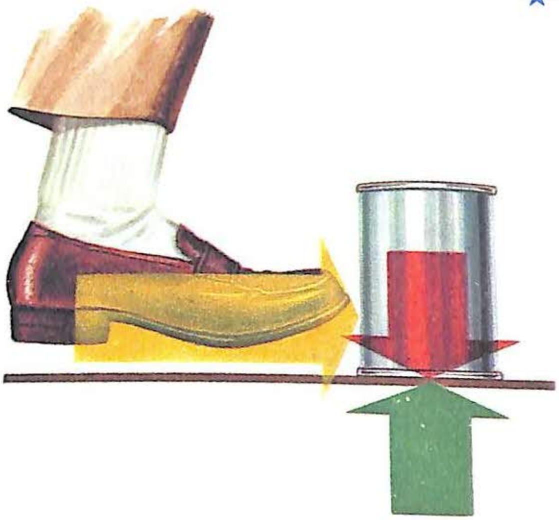


AN INVESTIGATION into a Dry Ice Jet Engine

Needed: an empty pint milk carton, a length of thread, a matchstick or toothpick, modeling clay, dry ice, tweezers, water, a paperclip

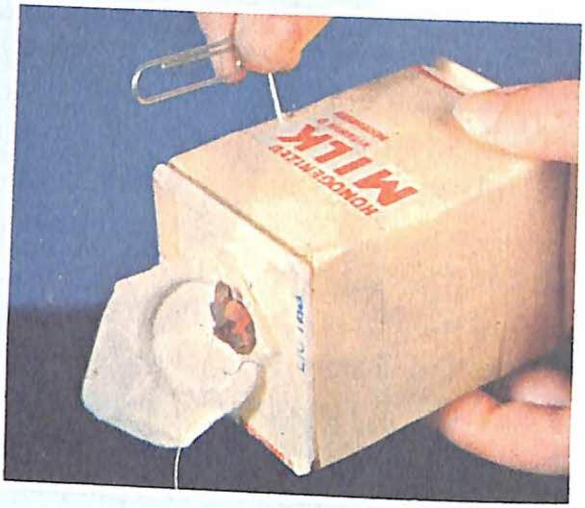
With the paperclip wire, make a small hole in the center of the carton top. Put the thread through the hole. Tie the matchstick or toothpick to the thread so that the stick will hold up the carton. Put clay around the thread at the hole so that there is no leak.

Make a small hole with the paperclip in one side of the carton as shown. ■ Do the same on the opposite side. Pour water into the carton to a depth of about an inch, and suspend the carton so that it can turn on the thread.

Use the tweezers to put two or three pieces of dry ice into the carton. ● **Caution: Do not hold dry ice with your fingers! It can cause painful blisters.** Close the cap tightly, and let go of the carton. What does the carton do? Here is what happened on one trial. ▲

Dry ice is solid carbon dioxide. The water in the carton gives enough heat to the solid to change it to carbon dioxide gas. Can you explain what the carton does as the gas escapes through the holes?

Additional Investigation: Predict what will happen if two more jet holes are made in the carton sides. Test your prediction.



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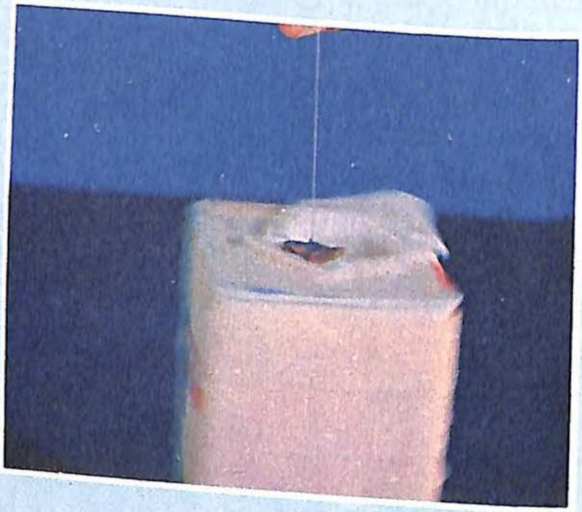

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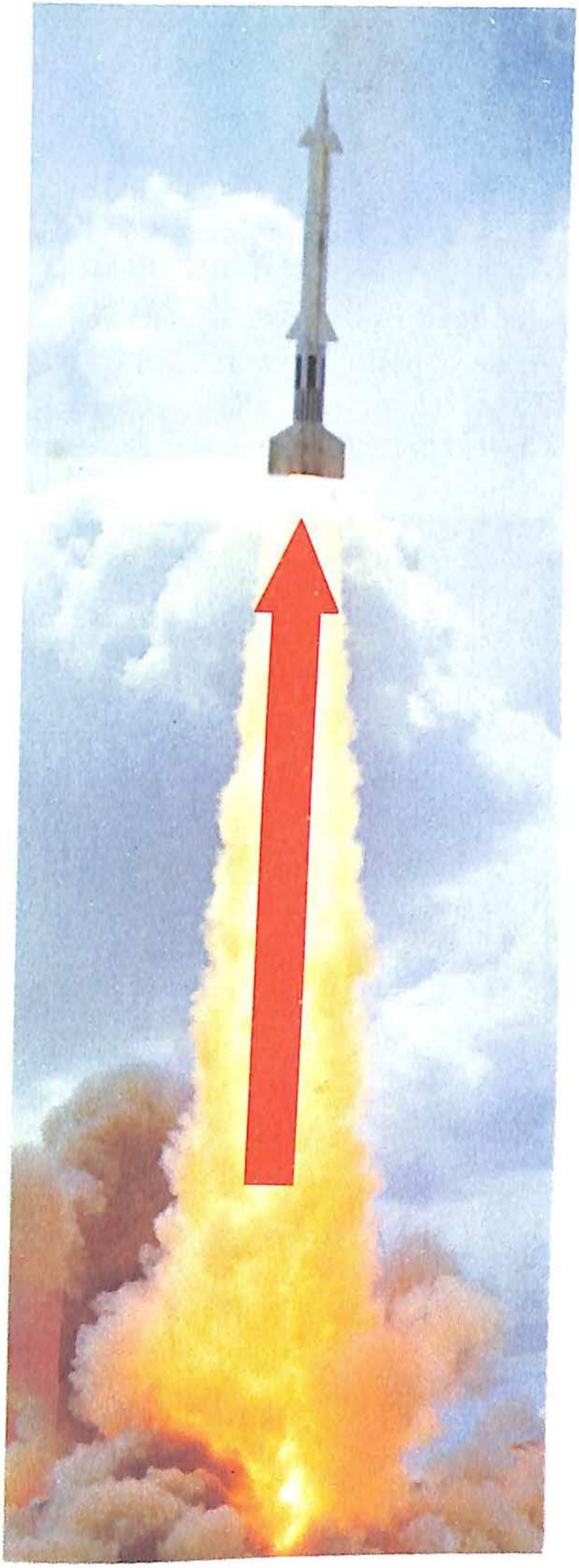


You Push It, It Pushes You

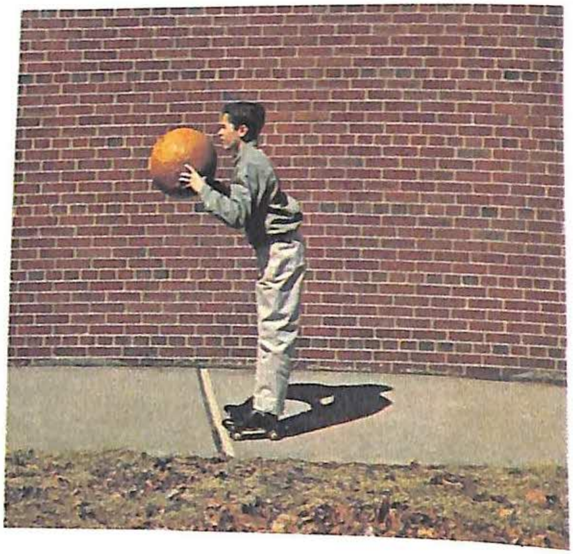
Observe the milk carton jet engine carefully. You will see that a jet of gas comes out of a hole in one direction. The carton moves in the opposite direction.

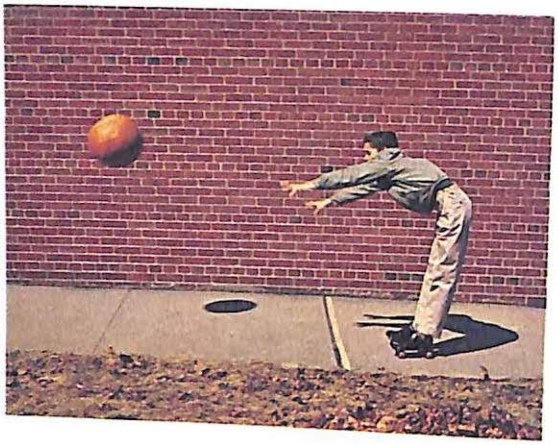
Remember that the jet of air from our balloon came out in one direction, and the balloon went off in the opposite direction. As hot gases squirt one way from the tail of a rocket, the rocket goes the other way. ■

Rocket, balloon, and dry-ice jet engine are all at rest. Then they begin to move. So an *unbalanced force* must be at work.

What provides this force?

Here is a photograph of an investigation. ● The boy on roller skates is holding a heavy ball. He is going to throw the ball away. Predict what will happen to the ball and to the boy. Then turn the page.





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Was your prediction correct? The ball goes away in one direction. The boy rolls away in the opposite direction. ■ *As boy pushes ball away, ball pushes boy away.*

As our dry-ice engine pushes gas away, the gas pushes the carton away.

Almost 300 years ago Isaac Newton stated the reason behind all this, although he never saw a giant rocket, or a boy wearing roller skates while throwing a ball. Newton stated that **every action has an equal and opposite reaction.** This is called Newton's **Law of Action and Reaction.**

Let's apply this law. For example, the boy on roller skates throws the ball away in one direction. This is the **action.** The ball pushes the boy away in the opposite direction. This is the **reaction.** The action has an equal and opposite reaction.

Here is another example. A spinning lawn sprinkler throws a stream of water in one direction. This is the action. The sprinkler spins in the opposite direction. This is the reaction. The action has an equal and opposite reaction. As the sprinkler pushes the water away, the water pushes the sprinkler away.

Action: A rocket forces hot gases away in one direction. ● Reaction: The hot gases force the rocket away in the opposite direction.

It is action and reaction that gets astronauts off the Earth.

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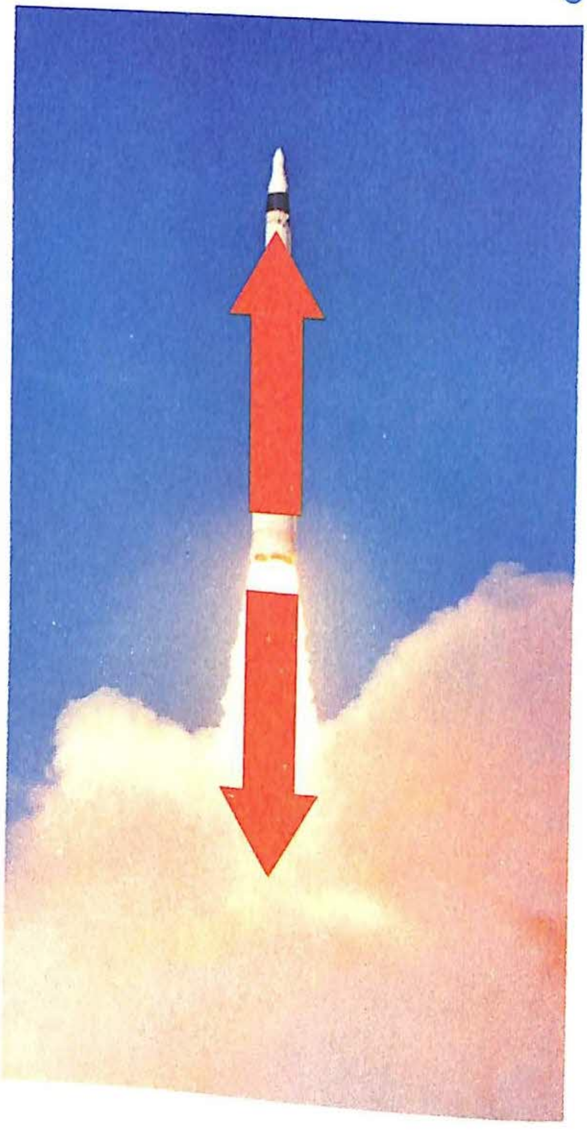

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BEFORE YOU GO ON

Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. To start something moving, you must use
a. a kick b. a force

2. The thrust which sends a rocket into space is
a. an unbalanced force b. a balanced force

3. Every action has an equal reaction in the
a. same direction b. opposite direction

4. In space, an astronaut sends a jet of gas to his right. He will move to
a. his right b. his left

USING WHAT YOU KNOW

1. An astronaut on the Earth can jump 6 feet high. How high can he jump on the Moon?

2. Some astronauts are planning a trip to the Moon. They estimate that their rocket will have to produce 3,600,000 pounds of thrust to get its mass off the Earth. How much thrust will be needed to get the same mass off the Moon?

3. The pilot of a rocket in space wants to turn to the left. His rocket has a small steering jet on each side of its nose. Which jet does he use? ▲

3. Man in Orbit

Men make a rocket and a fuel that can carry the rocket into space. One day men enter the capsule on top of the rocket and fasten themselves in. They wait as the countdown goes on, while the scientists, engineers, and technicians check every part of capsule and rocket. Then the moment comes. ". . . 4 . . . 3 . . . 2 . . . 1 . . . 0 . . . Lift off!" With a roar, rocket and men mount into trackless space.

Can they find their way through outer space—and back?

They can because their rocket obeys certain scientific laws. Strangely enough, some of these laws were stated about 300 years ago, by Isaac Newton. Let's look at these laws, for the concepts they state allow us to hurl men out into space and to bring them back.

Path of a Rocket

The huge rocket, perched on its launching pad, weighs 100 tons. The Earth's gravitational force holds it to the ground. Its fuel must first give enough energy to act against that gravitational force. Then the fuel must give the rocket a speed of about 18,000 miles per hour. The blast of hot gases from the burning fuel makes the unbalanced force that pushes the rocket off its pad.

At blast-off the rocket climbs into the sky with increasing speed. Its path is a long curve around the Earth. ■ After 3 minutes, when the rocket is about 100 miles high, its engine stops. But the rocket itself does not stop. It keeps on going, just as a thrown ball keeps moving after leaving the hand that threw it. Next, rocket and capsule separate. The capsule, although it has no engine, goes on with

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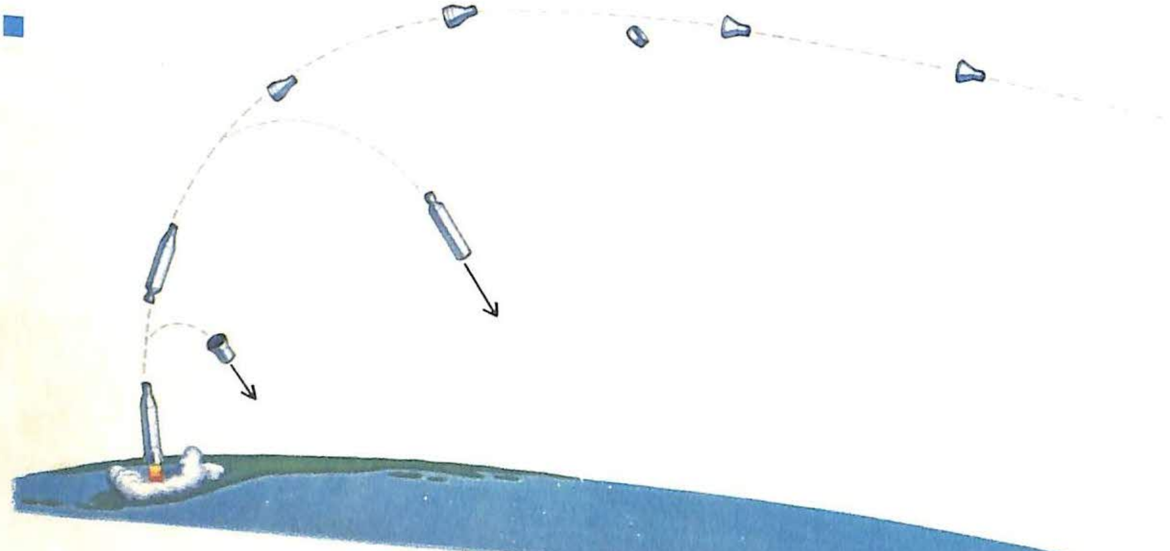

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the same speed. It takes a path that curves around the Earth. This curving path that a body takes in space around another body is called the **orbit.** Inside the capsule the astronauts read their instruments. Below them, on the Earth, other men read instruments, push buttons, and keep records. The capsule is on course, and on time! It is following the planned orbit.

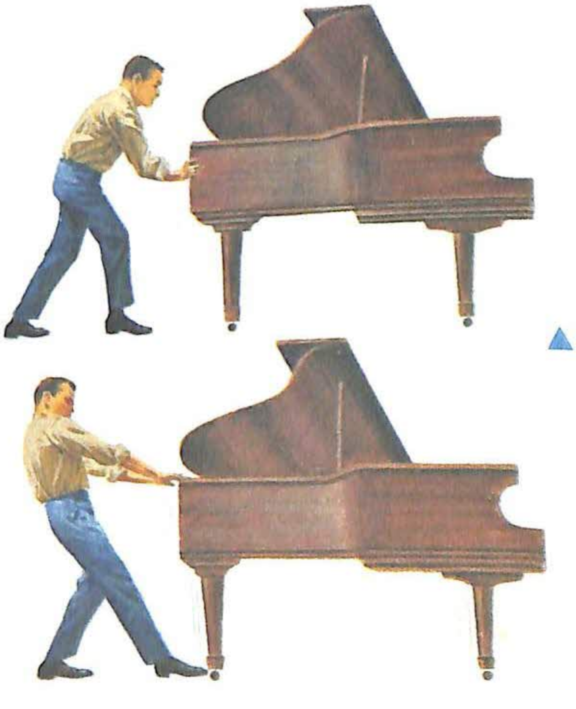
How is it possible to plan where a capsule will go?

Newton's Law of Motion

As you read this, you are probably sitting down. You know from experience that if you remain at rest in your chair, you will stay there. To get you out of the chair energy is necessary—yours or someone else's. *Things at rest tend to remain at rest.* You know this from experience. In fact men have known it for thousands of years.

Think now of an experience you might have in a moving car. The car stops suddenly. What happens to you? You keep on going, straight ahead, until brought to a sudden stop by a safety belt. ● In the same way, a bowling ball tends to keep going, until stopped at the end of the alley. A moving piano tends to keep moving. ▲

In other words, *things in motion tend to keep moving.* This is a rather new idea. Men have known this fact for only about 400 years. It is not as easy to see as the fact that a thing at rest tends to stay at rest. A great Italian scientist named Galileo (gal′-ə·lē′ō) put the two facts together. Galileo said an object tends to remain at rest or tends to remain in motion, because of its **inertia** (in·ûr′shə).



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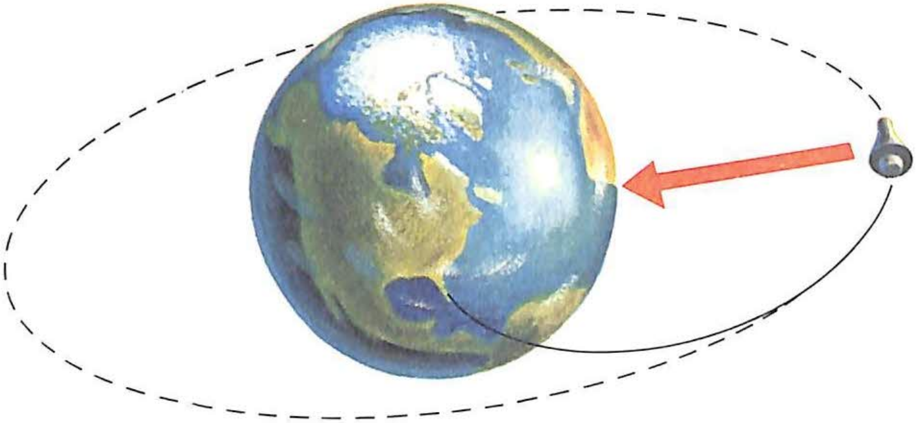

As scientists do, Newton built on Galileo's work and carried it further. Newton very neatly summed up how things behave, at rest or in motion, in a **Law of Motion:**

An object at rest remains at rest, and an object in motion continues in motion in a straight line, unless acted on by an unbalanced force.

This law is also called the **Law of Inertia.** For an object tends to remain at rest or continue in motion because it has inertia.

A rocket at rest on its launching pad remains at rest because of its inertia. It remains at rest until an unbalanced force, made by the hot gases squirting from its tail, puts the rocket in motion.

Out in space where there is no atmosphere, there is no drag of friction. Out in space a rocket in motion will continue in motion, with its engine stopped, because of its inertia. Out in space a capsule in motion should continue in motion, on and on. And, according to Newton's Law of Motion, it should go in a straight line.

As you know, however, the orbit of a capsule may curve around the Earth.

When this happens, then, according to Newton's Law of Motion, there must be an unbalanced force acting on that capsule. What force can there be, out in space, that can pull a heavy capsule from its straight path and steer it around Earth? What force holds a capsule in orbit? ■

Newton's greatest discovery gives us the answer.

Gravitation Everywhere

People used to believe that the stars, the planets, the Sun, and the Moon were completely different from the Earth. People were sure that whatever scientific laws men were able to discover on Earth had nothing to do with what happened in the mysterious heavens.

Then Newton saw an apple fall to the ground one day. He understood what made the apple fall. It was the Earth's force of gravitation.

Newton had a tremendous idea. Perhaps, he thought, the force of gravitation reaches out *beyond* the Earth. Perhaps this force reaches out into space, into the heavens. Gravitation pulls between the Earth and an apple. Perhaps gravitation pulls between the Earth and the Moon. ● Perhaps gravitation pulls between the Earth and the Sun, and between the Sun and every planet. Perhaps the force of gravitation reaches from star to star.

Perhaps, or so Newton thought, the force of gravitation reaches everywhere in the universe, holding it together!

Newton showed, by mathematics, that the Moon, Sun, and planets do behave as if gravitation is pulling them. He showed that the Moon follows its orbit around Earth because of gravitation between Earth and the Moon. Each planet curves around the Sun in an orbit that is shaped by the pull of gravitation between that planet and the distant Sun. Newton showed that gravitation is everywhere—that is, it is universal.

Newton's theory that gravitation reaches throughout the universe has so much evidence in its favor that scientists call it a law. It is called Newton's **Law of Universal Gravitation.**

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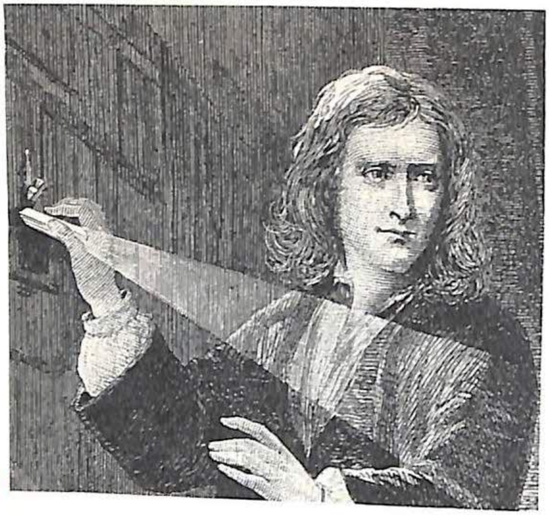
We can state it this way for the time being: **All bodies in space pull on each other with a force called gravitation.** This force acts to keep them in their orbits.

What holds a space capsule or rocket in an orbit around the Earth? Gravitation is the unbalanced force that pulls the capsule from a straight



path, and steers it around the globe of Earth. It is Newton's 300-year-old Law of Universal Gravitation that helps us today to predict accurately the orbit of a capsule. It helps us to know where a capsule or a rocket will be at any moment.

"No great discovery is ever made without a bold guess," Newton once said. ■ Newton's bold guess about universal gravitation showed us how to find paths in space.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The path of a body in space around another body is its
   a. reaction b. orbit
2. A body at rest tends to remain at rest because it has
   a. thrust b. inertia
3. A body in motion tends to remain in motion because it has
   a. thrust b. inertia
4. An object in motion continues in motion in a straight line, unless acted on by
   a. an unbalanced force b. a balanced force

B. Write a paragraph or two on this topic: "A Law Which Is Impossible to Break."

USING WHAT YOU KNOW

The inertia that a body has depends upon the body's mass—not upon its weight. If you took a bowling ball to the Moon, what would happen to the ball's weight? to its mass? to its inertia?

ON YOUR OWN 1. Make a large map of the solar system for your classroom bulletin board. On it show the orbits of space capsules sent out in the past year. You may find this book helpful: *Orbit*, by Hy Ruchlis, Harper & Row, New York, 1958. In this book, the scientific laws that govern the orbits of planets and satellites are described in an interesting way. Some investigations for further work are suggested.

2. You know that the greater the mass of a body, the greater its force of gravitation. The Sun has a greater force of gravitation than the Earth, because the Sun has a greater mass.

Does the Sun pull more on a space capsule going around the Earth than the Earth does? The Earth must have the greater pull, otherwise the capsule would be pulled over to the Sun. Then it is not only the *mass* of the body which acts on another body in space. What else is important?

The clue to the answer lies in these facts: The distance of the capsule from Earth is a few hundred miles. The distance of the capsule from the Sun is almost 93 million miles.

4. You Are in Orbit

You, too, are in orbit.

Right now you are on a space station. It is in orbit around the Sun. It is moving at a speed of 18 miles a second along its orbit, and it is spinning as it goes. Your space station is Earth.

Space Station Earth

Your space station is well equipped for a trip through space. It has food and water, air, heat, and many other things that you need. You have plenty of company, too. There are about 3 billion people on this space station, and more arriving every day.

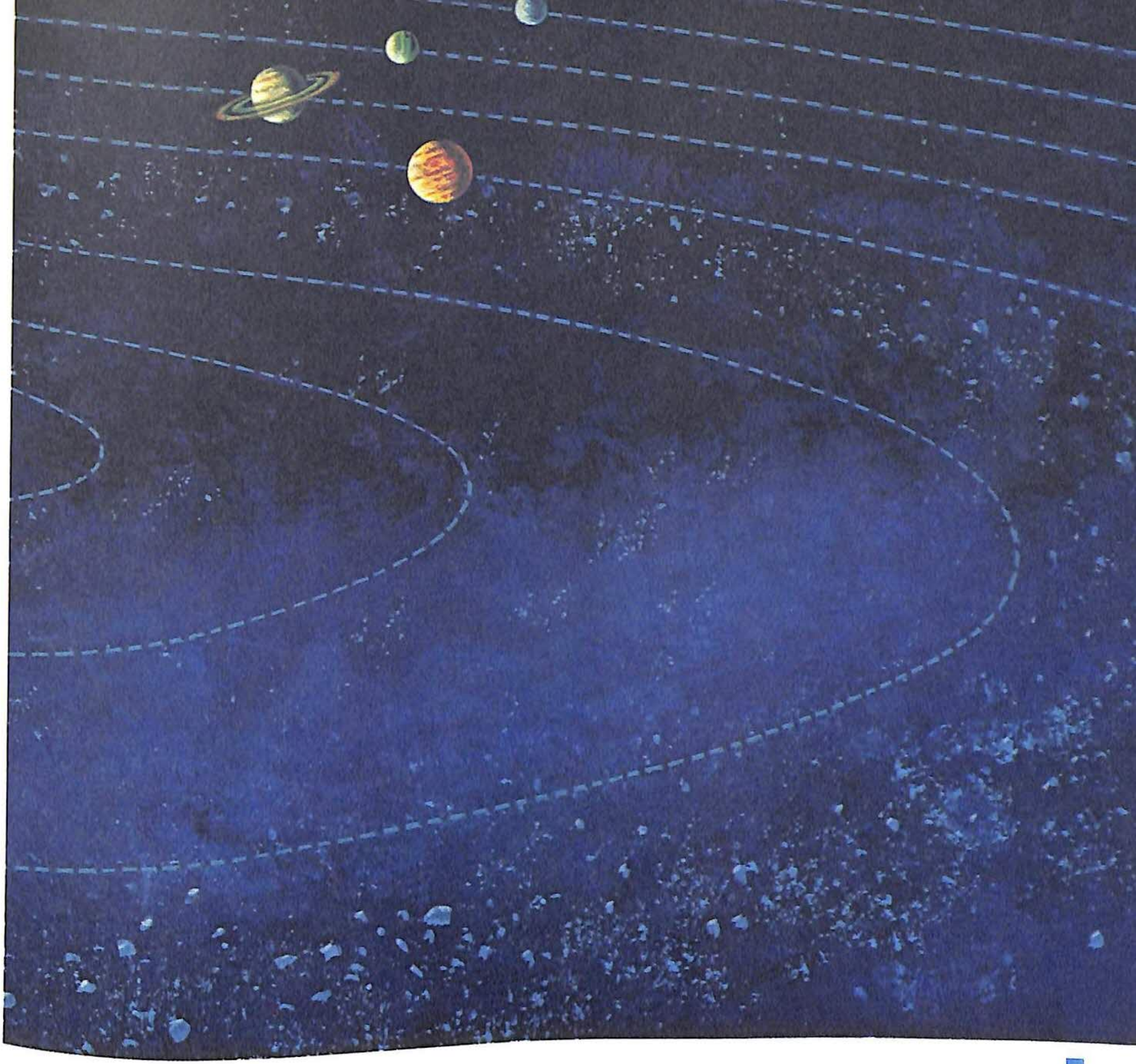
Scientists can predict the position of any space capsule they have put into orbit. There are now many of these **satellites**, man-made moons that are in orbit around the Earth. They are laboratories that send information to us. From them, we learn about the weather, the kinds of particles in space, and many other things.

We know, too, what the path of space station Earth is, and can predict where the Earth will be at any time. We are about 93 million miles away from the Sun, in our orbit around it.

In spite of the Earth's tremendous speed, it takes us about 365¼ days to make the trip around our orbit. That is, it takes us 365¼ days to make one **revolution** around the Sun.

While our space station is revolving around the Sun, it is rotating or spinning like a top as well. The Earth makes a complete **rotation** in about 24 hours.

One revolution of the Earth around the Sun takes one year. One rotation takes one day. You may know that the revolution of the Earth around the



Sun is the cause of the seasons and that rotation results in day and night.

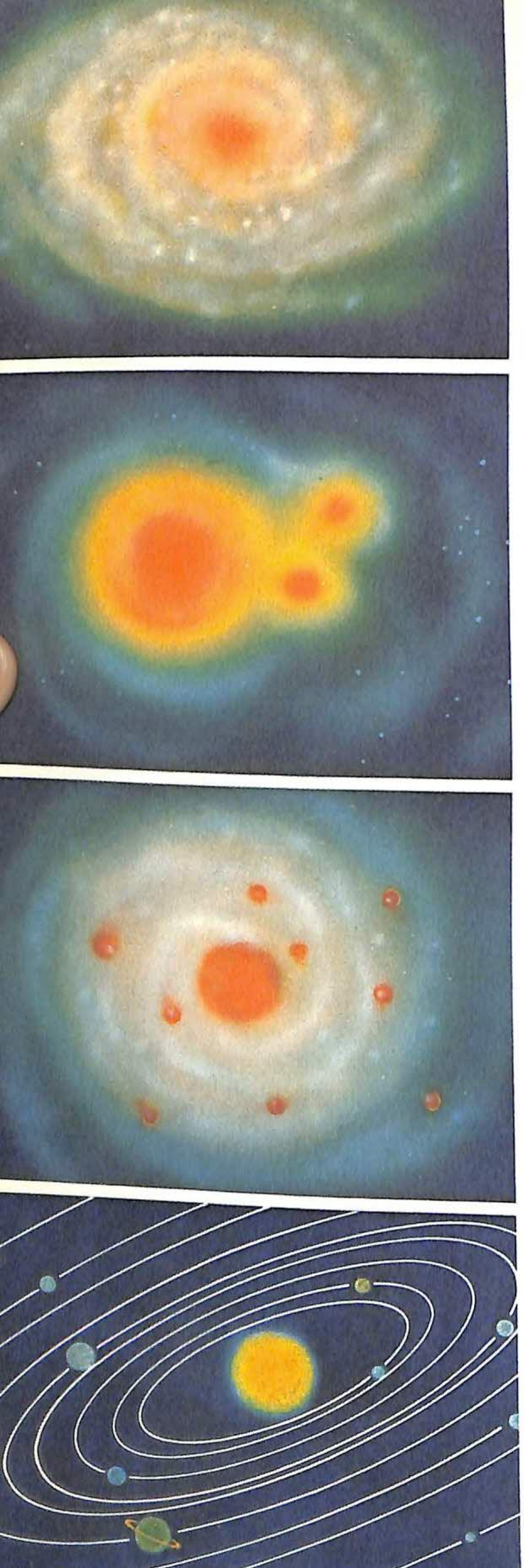
The Earth is in orbit around the Sun. The other planets in our solar system are in orbit around the Sun. The reason for this has to do with the way our solar system began.

🟦

A Cloud of Gas

Look at the drawing of our solar system. 🟦

You can see that the solar system has a flat shape, like a pancake. What explanation can there be for this? The pancake shape of the solar system sug-



gests a theory to scientists. The theory is that the Sun and all the planets came from one huge cloud of gas.

Long ago, this theory goes, a huge cloud of gas whirled slowly in space, among other clouds of gas and stars. Slowly, some scientists think, the ■ cloud of gas began to get smaller—and to spin faster. ■

As this cloud shrank, masses of the cloud began to come together. These masses were pulled toward each other by gravitational force. As the cloud shrank, these masses gathered more material and became larger. ● Over thousands and thousands of years the cloud shrank and formed the first planets. ▲ We call them **protoplanets** ● (prō′tə·plan′its). *Proto* means "first."

The protoplanets whirled around the mass of gas in the center. That mass of gas at the center later became the Sun. Each protoplanet got still smaller, and its heavier substances moved toward its center. Its lighter substances moved toward its surface. ◆

One of these protoplanets became the Earth. The Earth has a core of ▲ heavy material which we think is melted iron and nickel. It has a lighter crust, and a still lighter atmosphere. ★ It is in orbit around the Sun because both the Earth and the Sun were formed out of the same huge whirling cloud of hot gas. This is only one theory.

Of course, that very young Earth did not have any life on it. It was too hot and too near the young Sun. Today the Earth is farther away and gets about one billionth of the Sun's energy. Two billionths would burn us to a crisp. One-half of the energy we now receive from the Sun would not be enough, and our life on the Earth would not be possible.

Ninety-three million miles away from the Sun, we get the right amount of energy. Our station in space is in a very satisfactory orbit! Let us see what kind of orbit it is.

The Earth's Orbit

Of all the bodies in our solar system, the Sun has the largest mass. Therefore it has the greatest gravitational pull. Why, then, isn't Mercury, the planet nearest the Sun, pulled into the Sun? Why isn't the Earth pulled into the Sun?

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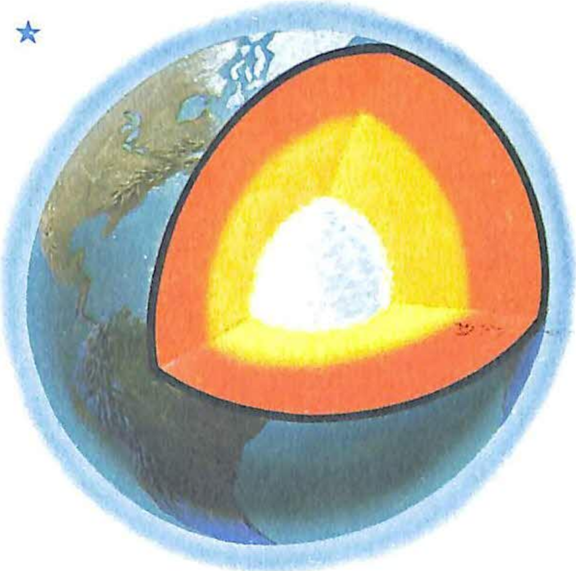

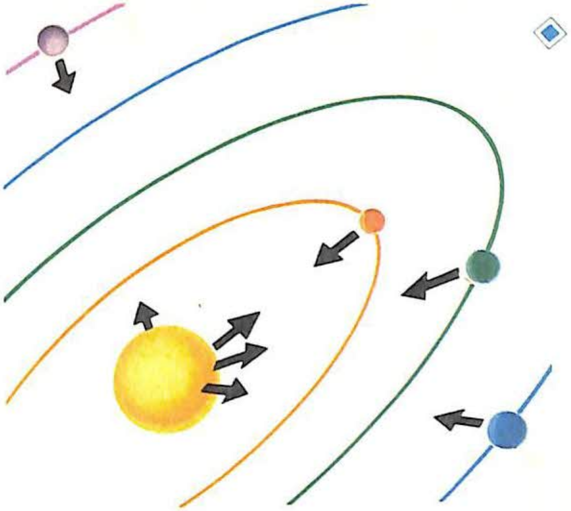

If a planet slowed down enough or stopped, it would certainly be pulled into the Sun. Our space station Earth, and the other planets, do not fall into the Sun because they are in motion around it.

As the protoplanets formed, they received energy from the great whirling cloud of gas, we believe. They continued to whirl around the gas cloud. When planets formed from the protoplanets, the planets went on whirling around the shrinking gas cloud that became the Sun. The planets in motion continued in motion, in curved paths around the Sun. It is the force of gravitation between the Sun and the planets that held them in orbit around the Sun. ◆

Two of Newton's laws help explain the orbit of a planet. The Law of Inertia helps explain why a planet remains in motion. The Law of Universal Gravitation helps explain why a planet is in orbit around the Sun.

Have you wondered what the shape of the Earth's orbit is like? Perhaps you have thought of it as a circle. If the Earth's orbit were a circular path, with the Sun at the center of the circle, the distance from the Earth to the Sun would not change. Let's look at some information about the Earth's orbit.

Approximate time of year	Approximate distance from Earth to Sun
March	93 million miles
June	94 million miles
September	93 million miles
December	91 million miles

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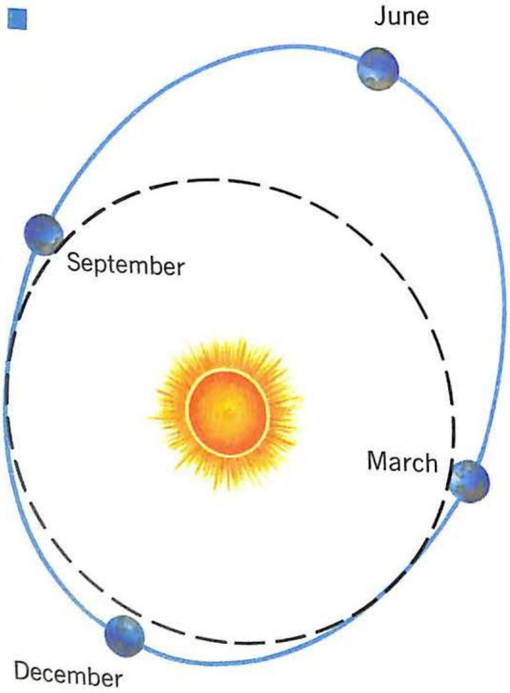

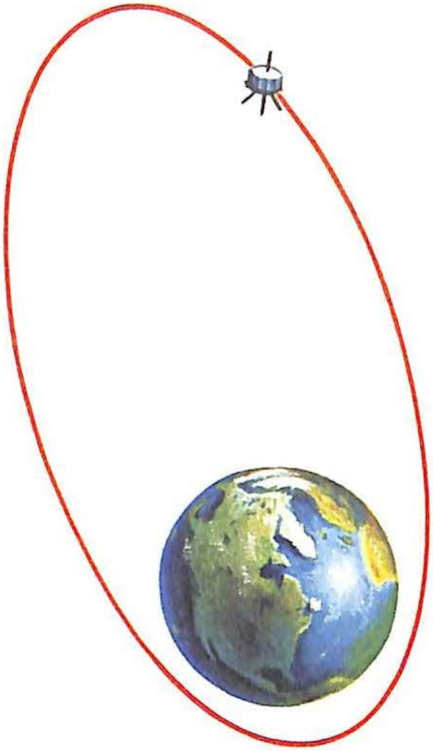

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Does this information show us that the Earth's orbit is a circle, with the Sun at the center? It does not, for the distance of the Earth from the Sun changes. What is the shape of the Earth's orbit, then? It took men a long time to say. Actually the shape of the orbit is a flattened circle. ■ This shape has a name; it is called an **ellipse** (i·lips′). The orbit of the Earth is an ellipse. In fact, the orbit of every planet in our solar system is an ellipse. The orbit of a space capsule around the Earth is an ellipse. ●

The ellipse, then, is an important shape—especially for astronauts, space engineers, and astronomers. You can find out some interesting things about an ellipse by doing the investigation on the opposite page.

AN INVESTIGATION into the Shape of the Earth's Orbit

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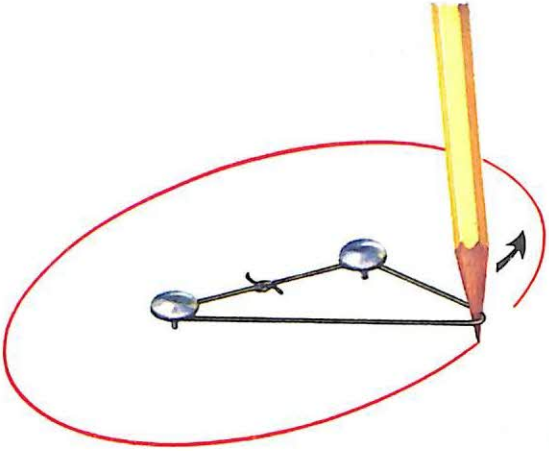

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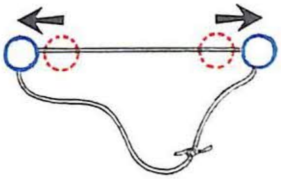

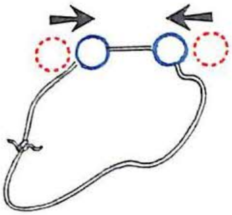

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Needed: a piece of paper, a pencil, a ruler, two thumbtacks, and a piece of string about a foot long

Place the thumbtacks firmly on the paper an inch or two apart. ■ Tie the ends of the string to make a loop. Put the loop around the thumbtacks. With your pencil inside the loop, tighten the string. Keep the string tight and move the pencil's point around the thumbtacks until the starting place is reached. The line formed represents an ellipse.

How will the shape of the ellipse change if the thumbtacks are moved farther apart? ● Make a prediction—then try it and see.

As you see, the shape of an ellipse depends on the position of two points (where the thumbtacks are). The Earth's path around the sun is an ellipse, and the Sun is at one of the points. Remember that it is the force of gravitation between the Sun and the Earth that pulls the Earth around in an ellipse.

Additional Investigation: How does the shape of the ellipse change as the thumbtacks are moved closer and closer together? ▲ What shape is the ellipse becoming as the thumbtacks are moved closer to each other? (This, too, is a possible orbit for a satellite.) Make a prediction, if you can, and test it.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. One theory of how the Sun and the planets came to be is that the solar system had its beginning in a cloud of

a. gas b. meteors

2. One reason why the planets in our solar system are together is that they began

a. together b. at different times

3. Mars spins like a top. This kind of turning is called

a. revolution b. rotation

4. Jupiter travels in an orbit around the Sun. One complete trip around the orbit is known as one

a. revolution b. rotation

B. Write a paragraph or two on this topic: "Before the Protoplanets and After."

USING WHAT YOU KNOW

1. Put the terms below in the order in which they appear in the story of how the planets were formed.

protoplanets
planets
cloud of gas

2. Why is the Earth not pulled into the Sun?

3. If the Earth is rotating in space, why are we not thrown off its surface?

ON YOUR OWN

The Earth for Sam, by Maxwell Reed, published by Harcourt, Brace & World, New York, 1960. The first few chapters in this interesting book describe the Earth's early years.

5. Moon in Orbit

You don't have to get into a capsule on top of a rocket to explore space. You *are* in orbit. You live on a rotating space station whirling around the Sun. From this space station you can get a fine view of space, if you look.

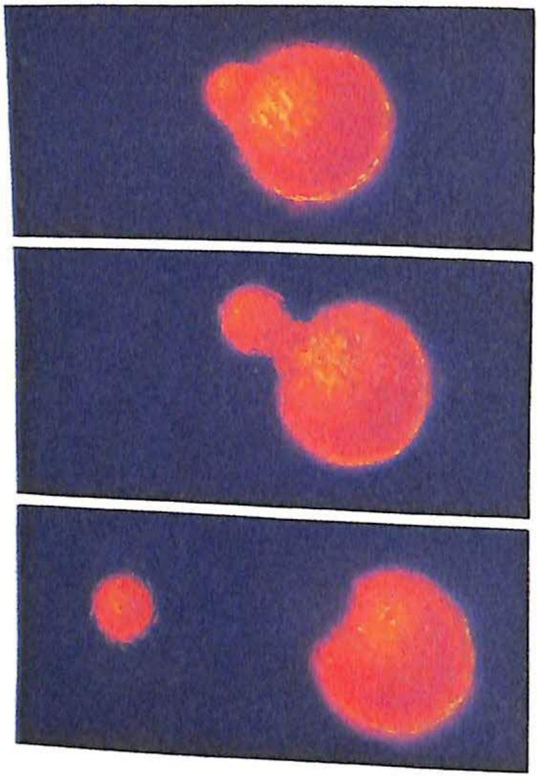
Look at our nearest neighbor in space, the Moon. ■ The Moon, our natural satellite, may have been the first satellite launched from our Earth.

George Darwin, son of the famous English scientist Charles Darwin, thought it might be so. He developed a theory about how the Moon might have been formed. He tried in his theory to explain these three observations that scientists had made.

Observaton 1: We know that the Moon is slowly moving away from the Earth, about 4 inches a year. The Moon used to be closer to Earth.

Observation 2: The Moon's surface seems to be made of materials much like those in the Earth's crust.

Observation 3: The Pacific Ocean looks like a huge bowl-shaped hole that has been filled with water. Other oceans don't look this way.



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Birth of the Moon

George Darwin's theory tries to explain those three observations. The theory is that when the Earth was still being shaped, a large piece of it tore loose. The mass that tore loose formed the Moon.■

The mass was made of the same material as the Earth's crust. Of course it was very close to the Earth at first. The hole made when this huge mass separated from Earth later became the Pacific Ocean. Thus did George Darwin explain the three observations.

Some scientists believe that George Darwin's theory explains most of the facts, but some others do not accept his theory.● They feel that more evidence is needed to show whether or not the theory is correct. When men reach the Moon, they will gather new evidence.

Scientists often disagree about theories. Scientists do agree, however, that any theory must give an explanation of the observations that have been made. To be accepted, a theory must

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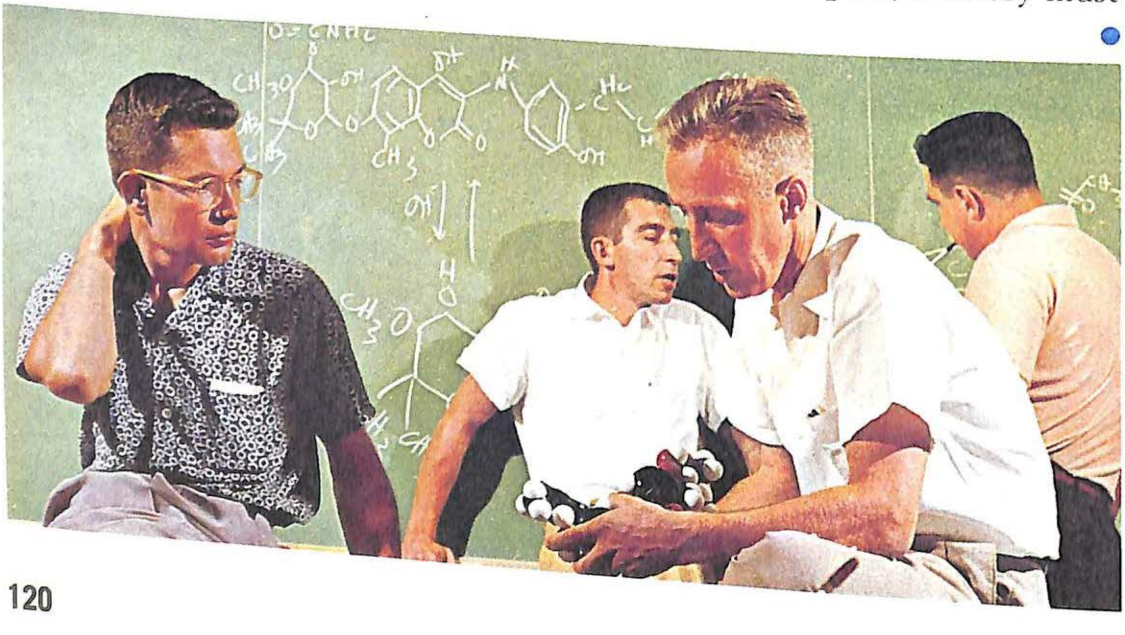

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stand the test of many investigations for a long time.

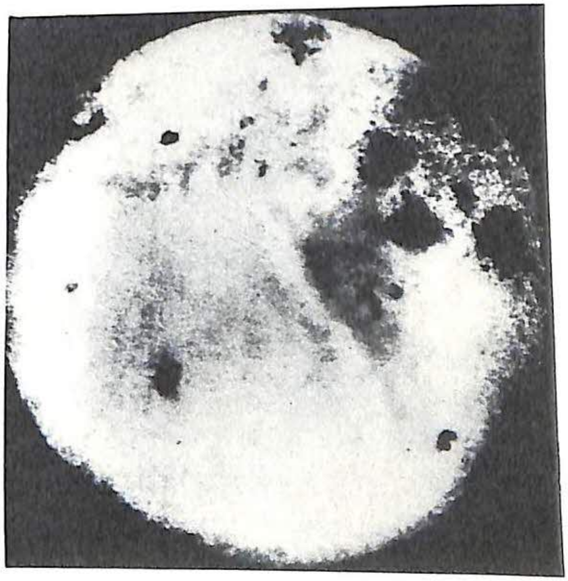
Newton's 300-year-old theory of universal gravitation has stood the test of time and investigations. It has explained the observations made of the motion of the Moon and the motion of some planets. Since then, the theory has been tested again and again. More and more observations have been made. New evidence has been found. Newton's theory has met the tests well. Because this theory has met so many tests, scientists now call it Newton's *Law* of Universal Gravitation.

The men who land on the Moon have a chance to test George Darwin's theory. They can gather evidence on how the Moon was born, and on why the Moon is moving away from the Earth. They also can learn more about the Moon's path around the Earth—about the Moon's orbit.

The Moon's Orbit

The Moon, our nearest neighbor in space, is only 240,000 miles away from Earth. (Our next nearest neighbor, the planet Venus, is more than one hundred times as far away.) The Moon's orbit lies around the Earth. One trip through its orbit takes the Moon a month. ▲

Strangely enough, the Moon always keeps the same side of its surface toward Earth. We never see the far side of the Moon from Earth. However, photographs of the far side have been taken from a space capsule. ◆ Because of this, we now know what



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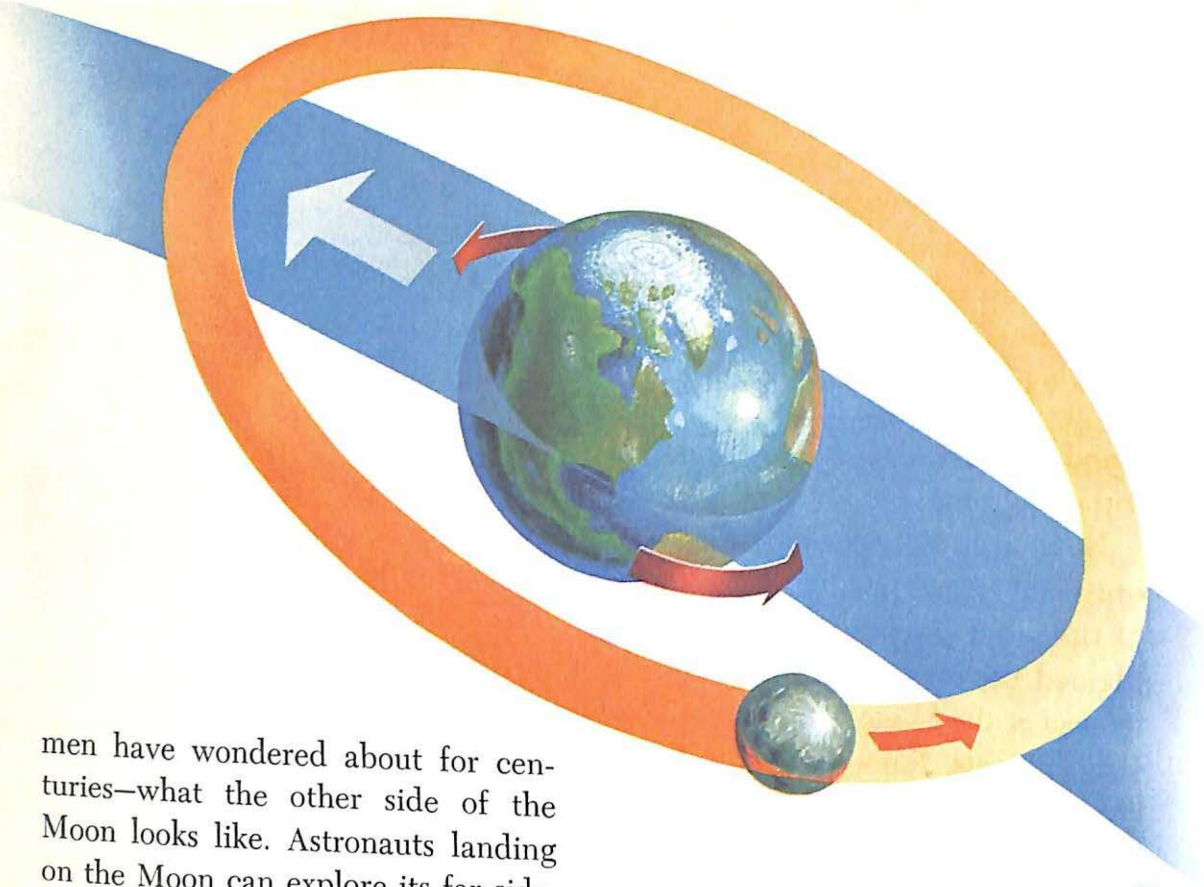


men have wondered about for centuries—what the other side of the Moon looks like. Astronauts landing on the Moon can explore its far side.

What is the shape of the Moon's orbit around the Earth? You can see for yourself. Draw a picture of an ellipse as shown on page 117. To get the right shape for the Moon's orbit, set the thumbtacks 3 inches apart, and use a loop of string that is $5\frac{1}{2}$ inches long.

Remember that, as the Moon swings around the Earth, the Earth is not standing still. For one thing, the Earth is spinning like a top, making one rotation in 24 hours. For another thing, Earth is moving along its own orbit around the Sun, taking $365\frac{1}{4}$ days to complete one revolution. ■

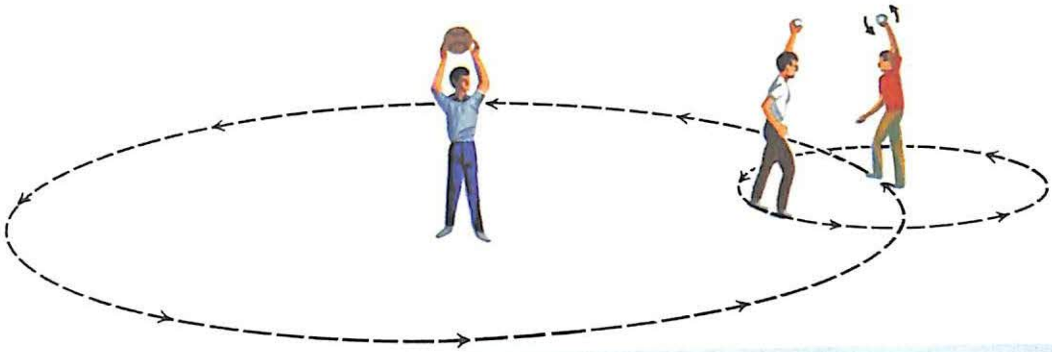
■

Nor is the Sun standing still! It too is rotating and revolving. And the group of stars which includes the Sun is rotating slowly.

Now if someone says, "Be absolutely still," you know that it's really impossible. You are on a rotating planet that is revolving around the Sun. The Sun itself is moving in space. You, the Moon, the planets, and the stars—including the Sun—are constantly in motion.

It isn't easy to get a clear picture in mind of these motions. However, the investigation on the opposite page shows how to make a helpful model.

MAKING A MODEL: A Planetarium



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Needed: a basketball, a baseball, a golf ball

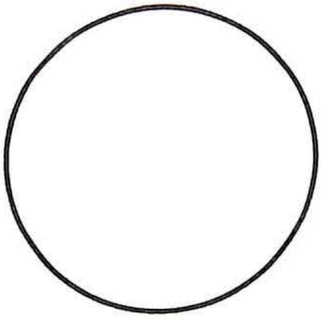
Let the basketball stand for the Sun, the baseball for the Earth, and the golf ball for the Moon.

One person holds the Sun. Another holds the Earth some distance from the Sun, as shown. ■ A third person holds the Moon near the Earth.

Now set the Earth and the Moon going. First, the Earth must rotate: rotate the baseball slowly. Second, the Moon must move around the Earth in an ellipse—always keeping the same side of the Moon toward the Earth. Now the Moon is in orbit. Third, as these things are going on, the Earth must move in an ellipse around the Sun—very slowly. Now the Earth is in orbit.

The Earth rotates once in 24 hours. The Moon makes one revolution around the Earth in 28 days. The Earth makes one revolution around the Sun in $365\frac{1}{4}$ days. Which should take the least time, then—the rotating Earth, the Moon moving around the Earth, or the Earth moving around the Sun? Which should take the most time?

Additional Investigation: Now use the model to answer this question: Which orbit, ●, ▲, or ◆, does the Moon make around the Sun?



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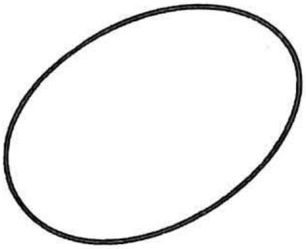

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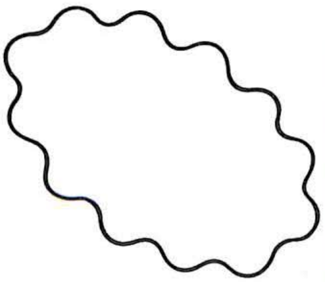

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BEFORE YOU GO ON

A. To fix in mind the concepts of this section, try to answer these three questions:

1. What is George Darwin's theory of the origin of the Moon?

2. Why don't all scientists agree with George Darwin's theory?

3. What is the shape of the Moon's orbit?

B. Write a paragraph or two on this topic: "Why the Moon Might Be Called Earoon."

USING WHAT YOU KNOW

1. A satellite is launched to orbit the planet Venus. It misses Venus, however, and goes into orbit around the Sun. What is the shape of the orbit?

2. What do you think is the difference between a theory and a law, so far as you know now? (You will learn more later about this difference.)

ON YOUR OWN

1. Who was George Darwin's father, and for what famous work is he known?

2. *The Moon, Earth's Natural Satellite*, by Franklyn M. Branley, published by Thomas Y. Crowell, New York, 1960. This book contains fine descriptions of the Moon and good pictures as well.

6. Man on the Moon?

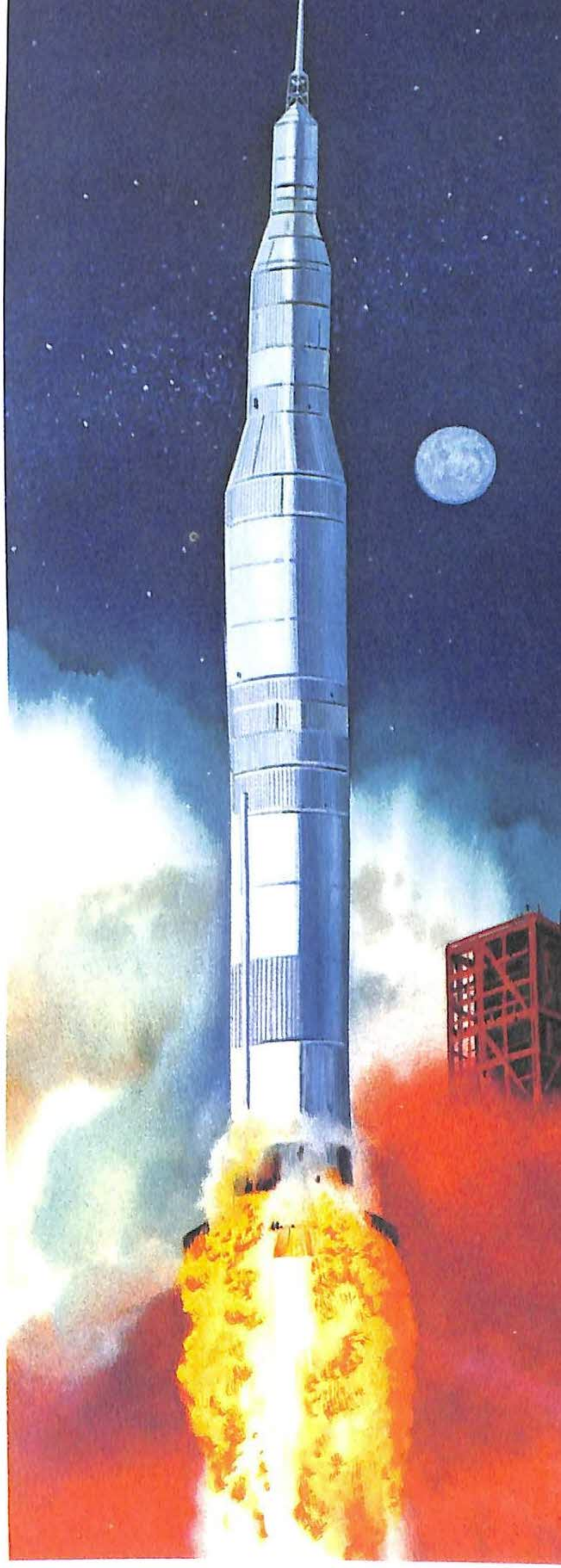
The three men enter the capsule of the spacecraft that will carry them to the Moon. They are not wearing pressure suits because the capsule is air-conditioned and pressurized.

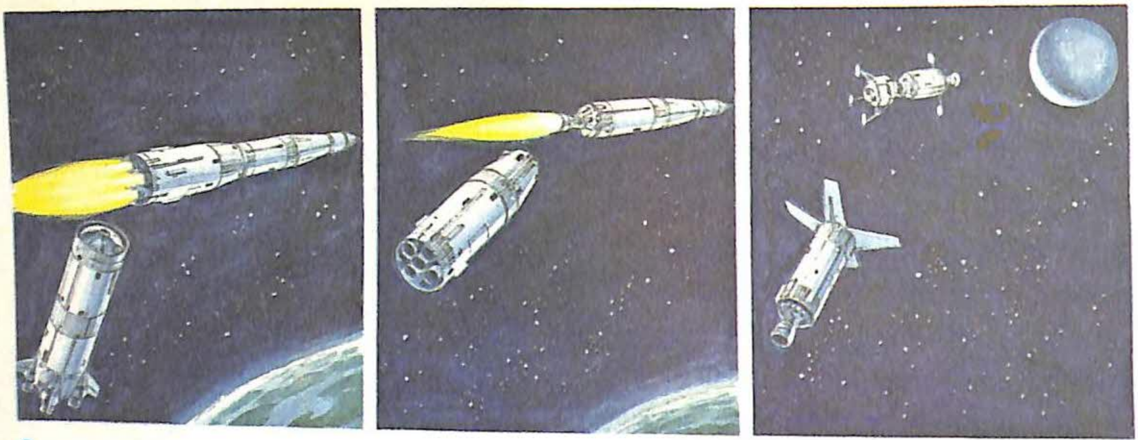
The capsule is perched on top of a giant rocket that has a cluster of ten rocket engines, rather than just one engine. The cluster of engines can throw a tremendous blast of gas backward. The reaction will be a tremendous force forward, called the thrust.

Each engine in the cluster produces about 1½ million pounds of thrust. The ten engines produce about 15 million pounds of thrust. The energy comes from a new fuel. It can provide force enough to overcome the Earth's gravitational pull and lift the huge rocket into space. ■

To the Moon

The astronauts are comfortable in the capsule as they await the end of the countdown. At blast-off the rocket rises smoothly, and it soon reaches a speed of 25,000 miles per hour—7 miles in a second! This is the speed the rocket has to have to escape from an orbit around the Earth. As the rocket climbs into space, the rocket engines and their empty fuel tanks are cut loose. Their job is done, and they drift away in their own orbits, as the drawings on the next page show. ●

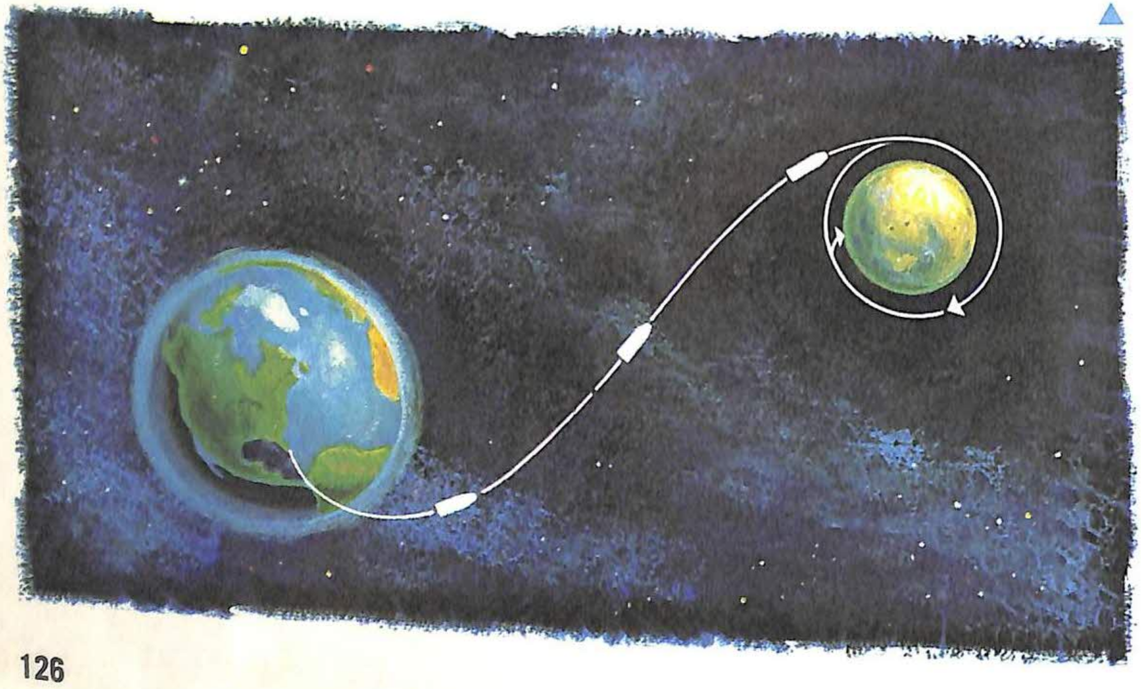




●

The course the astronauts must follow is shown in the diagram below.▲ The manned capsule can turn and be steered in space. The men in the capsule control its course and can even step out into space. Newton's Law of Action and Reaction works in space as well as on the Earth. A squirt of gas over to the left, for instance, will push the capsule to the right. As the capsule approaches the Moon, it is attracted by the Moon's gravitational pull. It moves faster and faster toward the Moon.◆ When the astronauts are near the Moon's surface, they turn the capsule around. Now its rocket engines are fired, and they produce a thrust to slow down the capsule's fall.★ The capsule eases down. Its blast blows away the Moon's possibly

▲



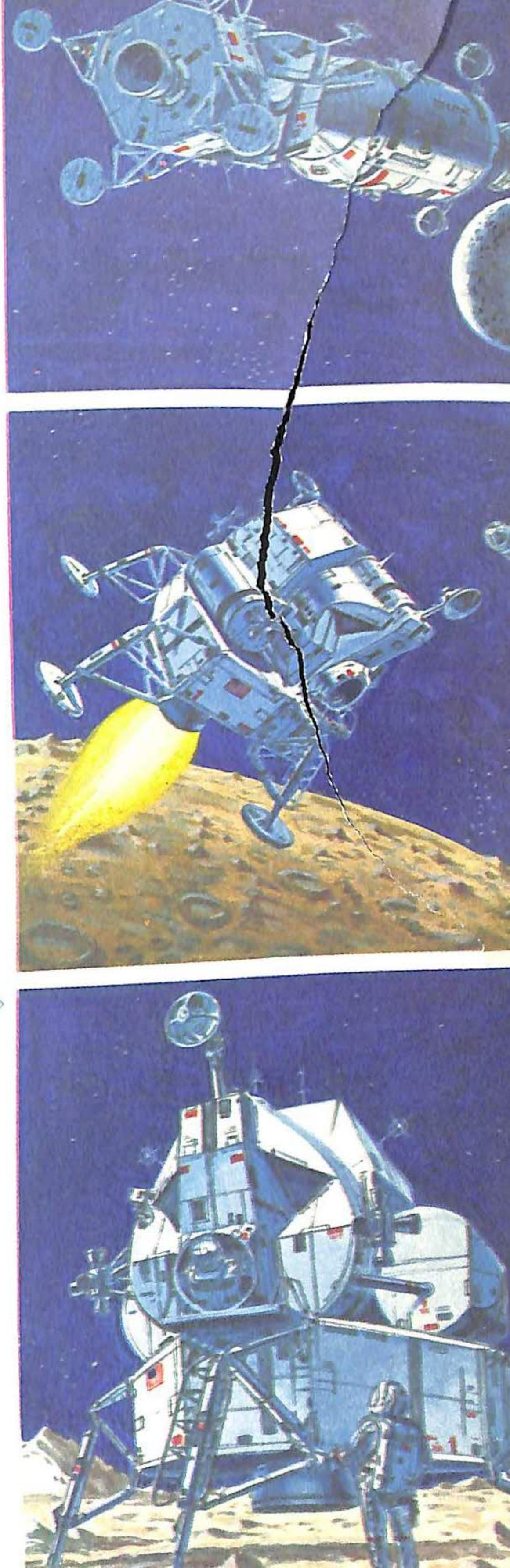
dusty surface and makes a hollow. The space capsule lands.

The men put on their space suits and leave the capsule. ◆ Each suit contains a heater, an air conditioner, a radio, and food. Each suit is pressurized, for the Moon has no atmosphere—no air and no water. During the day, the Sun beats unmercifully on the Moon's surface. The high temperature would kill any living thing not protected against it. The astronauts are well protected in their suits.

Each space suit weighed 200 pounds on Earth. How can a man move about and explore in such a suit? He can't, on the Earth. However, the Moon's gravitational pull is $\frac{1}{6}$ that of the Earth, you recall. On the Moon the suit weighs only $\frac{1}{6}$ of 200 pounds, or only $33\frac{1}{3}$ pounds. The astronaut himself weighs only $\frac{1}{6}$ of his Earth weight. Altogether, then, he is not carrying much of a load.

After exploring the Moon for a time, collecting samples of its surface materials, and making scientific observations, the astronauts return to the space capsule. When the Moon and the Earth are in the right position, the capsule blasts off from the surface of the Moon.

This blast-off takes only a little energy, as compared with the energy needed to leave the Earth. For one thing, the gravitational pull of the Moon is much less than the Earth's.



For another, the space capsule has much less mass attached to it than when it left the Earth. Much of the fuel has been used up, and the empty rocket shells have been left behind in space.

After a trip through space for about $2\frac{1}{2}$ days, the capsule goes into orbit around the Earth. The last of its fuel is used to slow it down as it reenters the Earth's atmosphere. As soon as it lands, scientists begin work on the information and samples brought back.

In time, perhaps, astronauts will be reaching for other places in our solar system.

BEFORE YOU GO ON

Tell the story of the main concepts of this section under the title "Landing on the Moon." Include

The rocket on the Earth
The thrust which sends off the rocket
The climb into space
Landing on the Moon
Walking on the Moon
The return to the Earth

USING WHAT YOU KNOW

1. Why does it take less energy for a space capsule to leave the Moon than to leave the Earth?

2. A rocket leaving the Earth for the Moon must reach a speed of 25,000 miles per hour. Why? What will happen to the rocket if it does not reach this speed?

ON YOUR OWN

In the days to come, space shot will follow space shot, and newspapers and magazines will have wonderful and exciting stories about them. Men have already stepped out into space. The Soviet Cosmonaut, Aleksei A. Leonev, in 1965 did this. Others will follow. Has an American astronaut left his space capsule? Has anyone yet reached the moon?

Why not write your own book about these events? You might call it *The Conquest of Space During My Early Years.* Use a notebook, or punched sheets that can be kept in a binder.

7. The Main Concept: Earth in Orbit

A model of the Earth's place in space is not hard to make.

Take a pan of water. Sprinkle some pepper on the water. With your finger, start the water circling in a kind of whirlpool. Some of the specks of pepper will sink a little below the surface. Take your finger out. You have a whirling cloud of circling specks of pepper. It is a rather flat, pancake-shaped, spinning cloud.

■

With a little imagination, we can change this pan of peppered water into a model of the universe. *Imagine that each speck of pepper is a star.* It is a whirling cloud of stars, spinning around a center. Observe how they move, for a minute or two.

Here is a cloud of stars photographed through a powerful telescope. ■ This cloud of stars is spinning in space, around a center, much as the specks of pepper did. We call this spinning group of stars a **galaxy** (gal′-ək·sē).

We live in a galaxy much like the one you've just seen. Our star, the Sun, is just one of the stars in our galaxy. Astronomers have been able to figure out what our galaxy looks like from a distance. ■ Notice that it is thicker in the middle than at the edges, and that our Sun is near one edge. How many stars are in this galaxy? Thousands of millions. Our Sun is just one of them.

Recall that around our Sun are nine planets. They are very small specks indeed in this spinning pancake of stars. And one of these small specks is our Earth.

Look again at the Sun's place and the Earth's place in the galaxy. How should the galaxy look to us from the Earth? When we look in direction A, *into* the galaxy, there are many stars before our eyes. When we look in direction B, *out* of the galaxy, there are few stars to be seen. ■

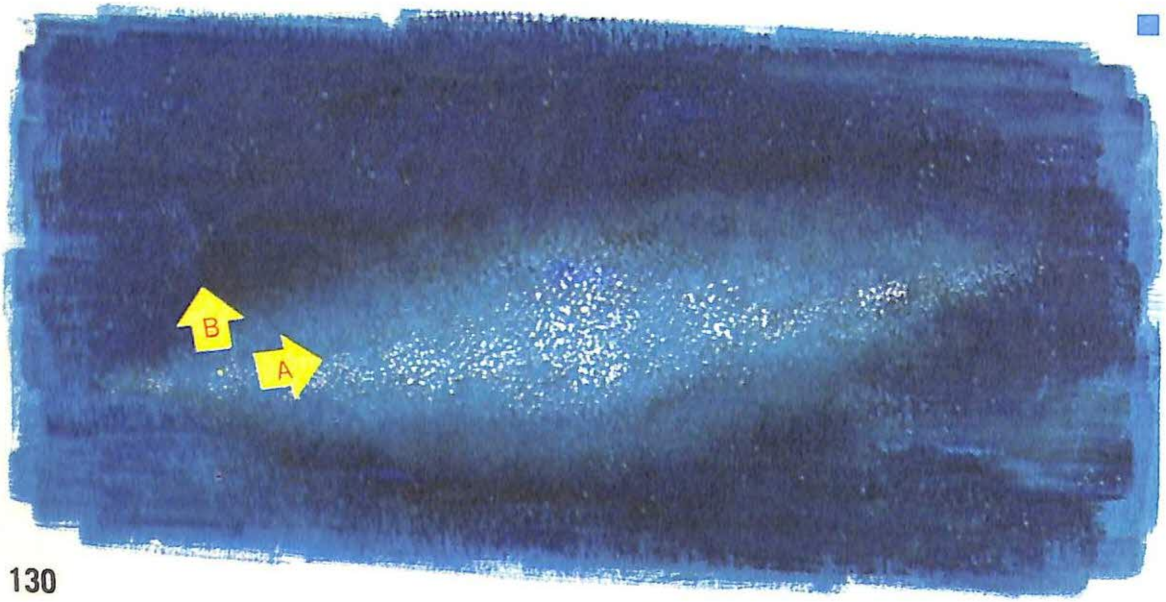
Look up at the stars some clear night and you will see in the sky a path studded with stars. ● Perhaps you know the name of this path; it is the Milky Way. When you look at the Milky Way, you are looking *into* the galaxy. But, when you look away from the Milky Way, you are looking *out of* the galaxy, and see fewer stars.

The galaxy we live in has a name. It will not surprise you to learn that it is called the Milky Way Galaxy.

Of course, the stars in our Milky Way Galaxy are really very far away from each other. Beyond our Milky Way Galaxy, at even greater distances, we can see through telescopes many other galaxies and many other stars.

Here, then, is our address in space. We live on one of nine planets, Earth. The nine planets revolve around one medium-sized star, the Sun. The Sun is only one star in a huge pancake of

■



stars, the Milky Way Galaxy. The Milky Way Galaxy is only one of the galaxies in space.

Gravitation

Stars are held together in a galaxy. Galaxies are held together in the universe. The planets in our solar system are held together in orbits.

Planets, stars, galaxies—all are held together by the force of gravitation. Every body in the universe attracts every other body. Sir Isaac Newton's theory, now called Newton's Law of Universal Gravitation, still satisfies us. It enables us to predict the orbit of a planet or a space capsule, the path of a falling apple or of a diving boy.

Objects attract each other with the force of gravitation. The Earth attracts you, and so you have weight. The force of gravitation on the Moon is only $\frac{1}{6}$ that on Earth. Your weight on the Moon then would be only $\frac{1}{6}$ of your weight on Earth. Your mass would not change, however, on Earth or on the Moon or anywhere in the universe.

Rest and Motion

An object at rest tends to remain at rest. It has inertia. To move an object at rest means to overcome its inertia. This takes energy. It can be the chemical energy from burning fuel in a rocket, for instance. It can be the mechanical energy of water turning a waterwheel. It can be electrical energy from a generator or a battery. It can be energy from within the atom. It can be heat energy or light energy. But unless energy is supplied, an object at rest remains at rest.

Suppose that energy is supplied to an object at rest, and the object moves. What happened to the energy? It provided a force. Your body supplies energy for the force to move a tennis ball, or pedal a bicycle, or lift a book. The fuel in a rocket supplies energy for the force to lift the rocket into space.

An object at rest tends to remain at rest, for it has inertia. An object in motion tends to stay in motion for the same reason. It continues in motion because it has inertia. The Law of Inertia was produced by Newton's mind and hard work: An object at rest remains at rest; an object in motion continues in motion in a straight line unless acted upon by an unbalanced force.

■

Unbalanced Force

In space there is no atmosphere, and so there is no friction. Thus the spurt of a jet of gas from a space capsule sends the capsule forward without any drag. A spurt of gas from the left side of the capsule pushes it to the right. Even here on the Earth, where there is plenty of friction, the same sort of thing happens. If you jump for the shore from a rowboat, the boat goes one way and you go the other.■ If you fall into the water you may think of Newton's Law of Action and Reaction: Every action has an equal and opposite reaction. Your action of leaving the boat has a reaction. The boat leaves you, and in the opposite direction. In the same way the action of the jet from a capsule has a reaction. The reaction makes an unbalanced force. The unbalanced force makes the capsule (or the rowboat) move.

A rocket is launched toward the Moon. Unbalanced force drives it out into space. Men have set it on its course carefully and exactly. To do this they have used concepts developed some 300 years ago—by Galileo and Newton.

Fixing the Main Concepts

TESTING YOURSELF

A. Test your understanding of important concepts in this unit by doing these problems.

1. How much would you weigh on the Moon?

2. Would your mass be more, less, or unchanged on the Moon?

3. The farther an object is from Earth, the smaller the force of Earth's gravitation. Since this is so, what must happen to your weight when you go up in an airplane?

4. If an astronaut could get completely away from gravitational force, what would he weigh?

5. A boy riding a bicycle to school had to stop suddenly. His lunch and books in a basket at the front of the bicycle were thrown out. Did they fall in front of him or behind? Why?

6. An astronaut in space steps out of his spaceship. He discovers that he has with him all the things he needs except, alas, the little jets which allow him to move around in space. But (for some reason) he has a fire extinguisher with him. How can he get back to his ship?

B. Test your understanding of concepts in this unit by using each of these key words and phrases in a sentence.

gravitation
weight
mass
thrust
Law of Inertia
ellipse
protoplanet
rotation
force
galaxy
unbalanced force
action
reaction
Law of Universal Gravitation
orbit
satellite

C. Test your knowledge with this quick check.

1. Out in space an astronaut wants to turn his capsule to the left. He should spurt a jet

   a. backward
   b. forward
   c. to the left
   d. to the right

2. Earth is in orbit about 93 million miles away from the Sun. It is held in orbit by the gravitational pull of

   a. the Sun
   b. the Moon
   c. all the bodies in the solar system
   d. all the bodies in the universe

3. A space capsule is shot out from the Earth to explore Saturn. It is packed full of instruments and has no astronaut aboard. On the capsule's way past Mars it veers and goes into orbit around Mars. This happens because

   a. the capsule has too much energy
   b. the capsule is caught by the gravitational pull of Mars
   c. we'll never reach Saturn; it is too far away

4. The reason for developing bigger rockets is to

   a. get more thrust
   b. carry less weight
   c. use less energy
   d. get less inertia

ON YOUR OWN **Investigations and Projects**

1. In the Library

a. Life exists on Earth. On what other planet might life exist? Why do you think so?

b. Sir Isaac Newton stated the Law of Universal Gravitation, the Law of Inertia, and the Law of Action and Reaction. For what other work is he known?

c. Look up the word *gravity* in a dictionary. What is the difference between *gravity* and *gravitation*?

2. Your Own Tracking Station

Space shots are taking place almost every day. Set up a bulletin board, at home or in the classroom, on which to track a space shot. Put up a map of the solar system. Then, with colored pins show the orbit of a rocket or satellite. Of course, you will have to follow the news of the space shot very carefully.

3. An Invention of Your Own

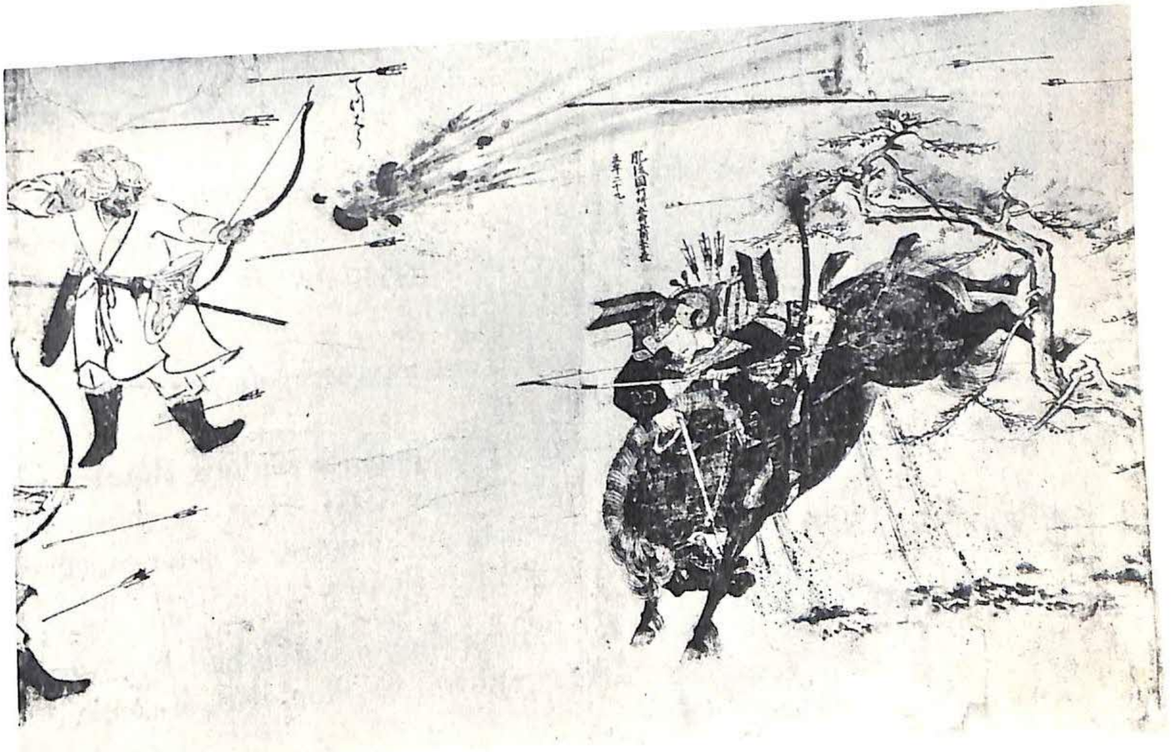
Make an invention based on Newton's Law of Action and Reaction.

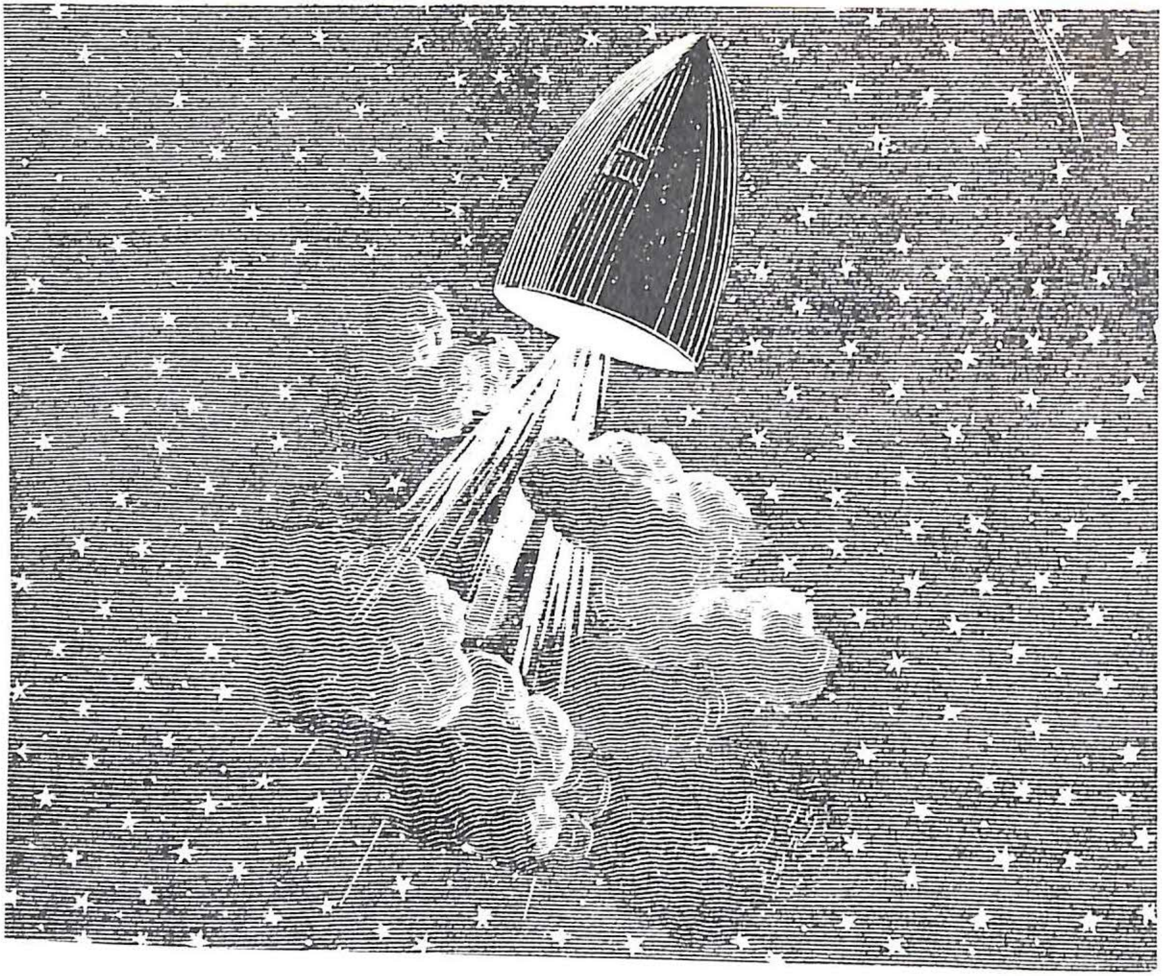
a. Move yourself on roller skates using this law. You may *not* use a motor, or jet, or any kind of fuel, or jet engine cartridges (such as a carbon dioxide cartridge).

b. Invent a jet boat that moves. Do not use a carbon dioxide or jet engine cartridge.

4. Plan a Project of Your Own

You might like to collect pictures or models of rockets. Why not show the development of the rocket? Begin in the 1920's as Dr. Robert Hutchings Goddard was developing his liquid-fuel models. Or start even further back, with the invention of the rocket by the Chinese. ■





FOR YOUR READING

1. In 1865 Jules Verne wrote *From the Earth to the Moon*, one of the first science-fiction stories. Look for it in the library. What fuel did Verne's Moon rocket use? Could that fuel actually carry a rocket to the Moon?

2. Look at these books. If one interests you, you might share a report on it with the class.

Galileo and the Magic Numbers, by Sidney Rosen, published by Little, Brown, Boston, 1958. This is a short biography of the mathematician and scientist. It is an especially good account of the work of a scientist.

Isaac Newton, by Patrick Moore, published by Putnam, New York, 1958. A biography of Newton, with an account of his discoveries.

GOING FURTHER

An Investigation

Here is a table showing how far a dropped object falls in a certain time. It also shows how fast the object is going.

FALL OF AN OBJECT

Time	The distance the object has fallen is	The object's speed is
at 0 seconds	0 feet	0 feet per second
in 1 second	16 feet	32 feet per second
in 2 seconds	64 feet	64 feet per second
in 3 seconds	144 feet	96 feet per second
in 4 seconds	256 feet	128 feet per second
in 5 seconds	400 feet	160 feet per second

Using this information, can you answer the following questions?

1. How far will a baseball fall in the first 4 seconds?

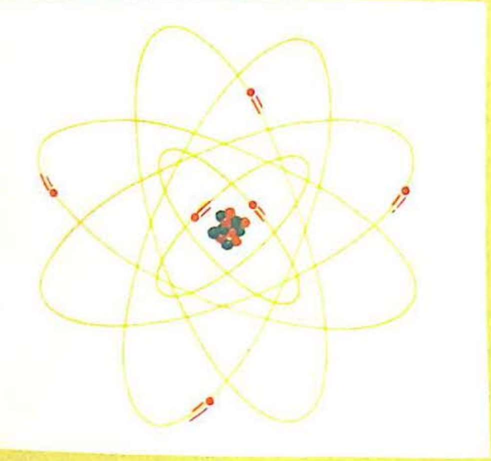
2. If a baseball were dropped from a height of 400 feet, how long would it take to reach the ground?

3. Which of these is true?
  a. The longer an object falls, the faster is its speed.
  b. The longer an object falls, the slower is its speed.

4. How fast will an object be falling at the end of the first 6 seconds?
(*A hint:* How much does the speed increase each second?)

S.C.E.R.T., West Bengal
Library
Calcutta
25/3, B. C. Road

A New View of Matter and Energy



We are rained on, snowed on, hailed on. We swim in streams, ponds, lakes, oceans. We walk on roads and meadows, we climb hills and mountains, we ride about in all kinds of vehicles. We see, hear, feel, taste, smell thousands of different things. We study the Earth and its neighboring planets, the Sun and other stars, solid rock, and open space. Yet we find that all these thousands of different things are in some ways alike. Let's remind ourselves of these important likenesses—the likenesses we found in our study of matter and energy.

A View of the World of Matter

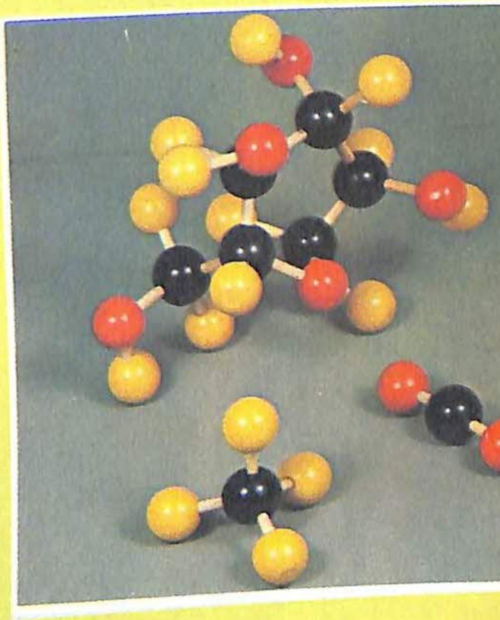
We see, for instance, that all the substances we know have likenesses. All substances can be classified into just three groups. Substances may be solids, or liquids, or gases, according to their structure. Rivers can be classified as young or old, according to their structure. Mountains can be grouped as young mountains or old mountains. Rocks can be classified as igneous, sedimentary, or metamorphic. This is one way we put things in order around us. *Things can be grouped or classified by their structure.*

We examine the structure of things closely and find another important concept. *All matter is made up of elements.* There are one hundred and three elements known (so far). Each element is made up of one kind of atom. We find that *all matter is made up of atoms.* ■

Nor do we stop here. For atoms are made up of still smaller particles, of protons, electrons, and neutrons. Whether it is an atom of iron or an atom of sulfur, an atom of carbon or an atom of uranium, it is made up of protons, electrons, and neutrons. Different atoms are simply made up of different numbers of these particles.

All matter is made up of particles. Particles make up different kinds of atoms. Atoms make up different kinds of molecules. For example, the element carbon can combine with other elements to form many different compounds. ● The carbon atom can combine with many different atoms to form many different molecules.

Atoms combine into molecules. Molecules break apart into atoms. As this happens, the number of atoms does not change. When carbon and oxygen atoms combine to form carbon dioxide, no atoms are lost or gained. When mercuric oxide is broken down into mercury and oxygen, no atoms are lost and no atoms are gained. In other words, no matter is lost and no matter is gained in these reactions.



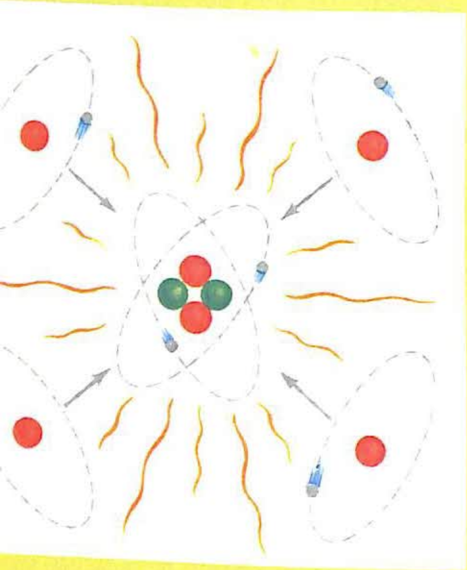
●

We find that the number of atoms remains the same. In a chemical change, *matter is not destroyed; it is only changed from one form to another.*

Indeed, we used to believe that matter could never be destroyed. We have learned otherwise.

Atoms of uranium, for instance, *can* break apart. We call the process radioactivity. When a radioactive atom breaks up, it destroys itself. It is no longer the same atom. It changes into other atoms, and into some energy as well. As this energy appears, a little matter disappears. So we now understand that *matter can be changed into energy.*

In the Sun, for example, matter is constantly being changed into energy. In the Sun, hydrogen atoms are changed into helium atoms. ■ As hydrogen is changed into helium, the hydrogen atoms are destroyed. Some of the matter of which the hydrogen atoms were made is changed into energy.



■

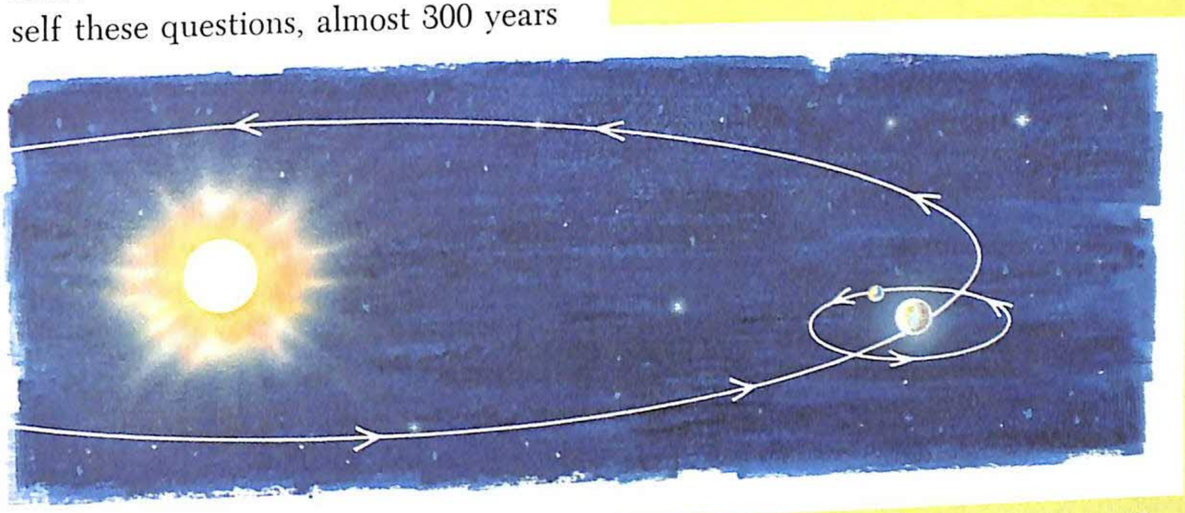
Matter can be changed into energy. So now scientists say, *matter can be changed into energy, and the total amount of matter and energy in the universe remains the same.* Nothing is lost.

Energy and Motion

This Earth, this collection of atoms, is a planet. It is one of nine planets in our solar system. Like all matter, the

Earth doesn't remain unchanged. As you have learned, for instance, it is constantly changing its position. Like the other planets, the Earth is in motion around its star, the Sun.

How is it that the Earth moves around the Sun? How is it that the Moon moves around the Earth?● Isaac Newton must have asked himself these questions, almost 300 years ago. His answers gave us two very important concepts.



One of these concepts helps us to understand how it is that the Earth continues in motion. The Earth and the Sun were formed from the same vast whirling cloud of gas in space. As the cloud whirled, the early planets began to form. These protoplanets, coming from the whirling cloud, were in motion too. And they continued in motion. For, as Newton's Law of Inertia states, *an object at rest remains at rest, and an object in motion continues in motion in a straight line, unless acted on by an unbalanced force.*

However, the Earth's motion is *not* in a straight line. The Earth moves in an orbit around the Sun. The Moon's motion is not in a straight line. The Moon is in orbit around the Earth. What unbalanced force pulls the Earth and the Moon out of a straight line? We know it is the force of gravitation. It is the force of gravitation between the Sun and the Earth that pulls the Earth out of motion in a straight line. Since the mass of the Sun is much greater than the mass of the Earth, the Earth goes in orbit around the Sun. It is the force of gravitation between the Earth and the Moon that causes the Moon to move in orbit around the Earth.

The greater the mass of a body, the greater is its gravitational pull. The nearer two bodies are, the greater the gravitational pull between them. Newton's Law of Gravitation made these things clear by stating that *all objects are attracted to each other by the force of gravitation.*

The two laws, that of universal gravitation and that of inertia, help us to understand many things that we observe on Earth.

Once an object is in motion, we can change its direction with an unbalanced force. The force may be gravitation, for instance. If a rocket goes too near the Moon, it may be pulled into the Moon by the force of gravitation. ■

An astronaut in space can make use of another of Newton's Laws, that *every action has an equal and opposite reaction*. This is another great concept in science. An astronaut sends a jet of gas in one direction from his capsule in space. The capsule moves in the opposite direction. It does so because the action of the jet has a reaction, which causes the movement of the capsule. The energy of the rocket fuel is changed into a different form of energy. It is changed into the energy of motion of the rocket.

In our study of the Earth, we have come upon important concepts.

Matter is made up of particles.
Matter can be changed from one form to another.
Energy exists in different forms.
Energy can be changed from one form to another.

And we have come upon a new understanding, a new concept, arising from our search into the way the world works. This is:

Matter can be changed into energy.

This concept needs further building. It will be built up, by you, as you go further into science.

As we begin to understand these great concepts, we begin to understand how the world works.

CONCEPTUAL SCHEME

A living thing is the product of its heredity and environment.

Unit Four

BUILDING BLOCKS OF LIVING THINGS

(*Text pages 144–189*)

UNIT CONCEPT
The cell is the unit of structure and function; a living thing develops from a single cell.

A Preview of the Concepts

The child is introduced to the smallest unit of living things, a cell. He gains an understanding of essential living processes which take place in one cell or in many cells. The child begins to comprehend that, beginning with chromosomes which set the cell pattern, organisms grow, develop, and multiply through cell division.

A VIEW OF THE UNIT

Children begin to understand the basic operation of processes such as oxidation and diffusion within a living cell. The role of the huge molecule ATP (adenosine triphosphate) in the cell's matter-energy cycle is introduced and explained after a study of life processes in the leaf cell. Such introduction will make the concept infinitely easier for children, who will meet it again and again in science courses through high school and college.

The text presents to children the micro-world of single-celled organisms in a drop of pond water and moves on to cell multiplication and division, and then to cell differentiation and specialization in many-celled organisms. It shows how protoplasm, the living stuff of cells, is built from elements and compounds drawn from the Earth's crust and air envelope. It utilizes the development of a frog from a single egg cell to illustrate the whole reproductive cycle.

The unit gives the child insight into the cell as the unit of structure and function, and he learns that every living thing develops from a single cell. Thus, his understanding that living things are the products of their heredity and environment is strengthened and broadened. The author's own words at the end of the unit summarize the inferences the child has been making during his study and investigations:

"Cells are the building blocks of living things. Within each cell are chromosomes. Within each chromosome is the substance DNA. . . . Because the chromosomes and their DNA duplicate themselves living things receive the characteristics carried by their parents." As one section develops the concept, ducks always "hatch ducklings"; frogs, frogs.

The Care and Use of Microscopes

A view through a microscope or a telescope lends important dimensions to anyone's perception of the universe. In today's world, elementary-grade children need early and continued experience with one or the other instrument. Since microscopes require no special planning for use during out-of-school hours, they may be used in or out of class at all grade levels. One kindergarten teacher secured the loan of a microscope through a parent who was a physician. The children had a rich experience as they looked through the microscope at a variety of objects. The rule was to keep one hand on the arm of the microscope, the other on the table, a procedure which prevented accidents to both child and microscope. The teacher did the focusing. A teacher of upper-grade children made a wooden base and a strip that could be fastened across the base, or feet, of the microscope. This base was attached to the window sill for best light. When the microscope was set up in position, the wooden cross-strip, when turned across the feet of the microscope, kept it from being tipped over. Older children can take pride in learning proper handling of a microscope.

Children who have home microscopes can demonstrate their care and use. A series of cartoon drawings made by children could reinforce "Do's and Don'ts for Users of Microscopes."

Enlarged high school models and charts of cells, if available, should be used sparingly. They tend to confuse rather than clarify.

For further details and suggestions see pages 64–65, *A Sourcebook for Elementary Science.*

SUPPLEMENTARY AIDS

All films and filmstrips are in color. Names and addresses of distributors of films and filmstrips are on page F–25.

Films

What's Alive? (11 min.), F.A. Helps toward an understanding of the activities that distinguish living from nonliving things. (Intermediate)

Animals in a Micro-Universe (11 min.), E.F.D. Cinephotomicrography pictures the factors accounting for complexity of life in microscopic organisms, the relationships among minute animals in a micro-environment, and the teeming millions around us everywhere. Wherever moisture is found, life will be found also. Shows Protozoa, Crustacea, Rotifera, colonial Protozoa. (Intermediate)

Microbes and Their Control (13 min.), F.A. Microbes are living things too small to be seen with the eyes alone. In order to grow, they need food, moisture, and warmth. We can control their growth. (Primary, Intermediate)

Microscopic Life: The World of the Invisible (14 min.), E.B.F. Describes methods of classifying the many forms of microscopic life and examines the life processes of both one-celled and many-celled animals; methods of food gathering, digestion, and reproduction. Illustrates interdependence of plants and animals in fresh-water environment. (Intermediate, Junior High)

Filmstrips

Introduction to the Microscope (42 frames), S.V.E. Explains the functions of each part of the microscope. Shows how to get it ready for use and how to apply it in examining specimens. (Junior High)

Introduction to Algae (35 frames), S.V.E. How a specimen is prepared for investigation and how the nucleus of an alga cell is made visible under the microscope. (Junior High)

Introduction to Protozoa (32 frames), S.V.E. Tells how to prepare a culture of protozoa, and how to make a satisfactory examination of it. (Junior High)

Science Reading Table

Starred titles are especially recommended for content and reading level. Addresses of the publishers are on page F–24.

°*Adventures with a Hand Lens* by Birger Richard Headstrom, Lippincott, 1962. A hand lens opens new views of the immediate environment. Fifty explorations of nature by use of this simple and inexpensive tool are suggested. The activities may be individual or class projects. (Advanced)

The Community of Living Things in Field and Meadow by Etta Schneider Ress, Volume One of The Community of Living Things, in five volumes, Creative Educational Society, 1956, in cooperation with the National Audubon Society. The plants and animals, with full-page photographs opposite each page of descriptive text, are depicted in ecological relationship with their environment. Attention is given to classification; includes chapters on "Cold-Blooded Animals of the Field," "Birds: Warm-Blooded Animals with Feathers," and "Mammals: Warm-Blooded Animals with Hair." (Average)

The First Book of Microbes by Lucia Z. Lewis, Franklin Watts, 1955. Introduces the cell as the basic unit of life. Describes types of animal and plant microbes including amebas, paramecia, algae, molds, yeasts, and bacteria. Brief account of scientists who discovered and studied microbes. (Average)

°*Play with Plants* by Millicent E. Selsam, William Morrow, 1949. Promotes concept development of the relationship of the seed and growing plants to the environmental factors of heat, light, and moisture. Instructions for investigations are accompanied by illustrations. (Easy)

Pioneer Germ Fighters by Navin Sullivan, Atheneum Publishers, 1962. Biographies of scientists important in bacteriological study and the continuing fight against disease. The interdependence of the work of scientists is apparent. (Average)

The Community of Living Things in Fresh and Salt Water by B. Bartram Cadbury, Creative Educational Society, 1956, in cooperation with the National Audubon Society. The concept of water as a requirement for the basic life processes of plants and animals is presented in a page of text opposite a full-page photograph of each plant and animal. Some attention to the activities of man as concerned with streams, lakes, coasts, and offshore waters is included. (Average)

Wonders Under a Microscope by Margaret Cosgrove, Dodd, Mead, 1959. An introductory book on the use of the microscope as a tool for exploration. Concentration is on the viewing of larger specimens to help the child develop dexterity in use of the instrument. (Average)

The World of the Microscope by L. J. Ludovici, Putnam's, 1959. A history of bacteriology describing the work of important researchers including Jenner, Pasteur, Lister, Koch, Reed, Fleming, and Salk. The development of sanitation and continuing discovery of measures of control of diseases are described, including modern "wonder drugs." For the particularly interested and capable reader. (Advanced)

What Is a Cell? by Fred M. King and George R. Otto, Benefic Press, 1961. Simple definition and description of cell structure, grouping, specialization, and reproduction. A primer of cell study, presenting an overview of topics important to concept development of the cell as a unit of living matter. Less capable readers may find the book useful if helped with clarification of words such as "colony," "tissue," "cell," and "organ," which most children have encountered with different meanings. (Average)

INTRODUCING THE UNIT

Many children, even in primary grades, can tell you that the smallest bit of anything in the world is a *molecule*. Quite a few know and use the word *atom*. It is curious, however, that so few children have so little conception of the *cell* as the smallest functional unit of all living things. An inventory of the conceptions—and misconceptions—of the "stuff" of which we are made and how it functions to keep us actively alive is a useful approach to the main concept and subconcepts of this unit. As the children examine the illustration and the opening text of the unit, encourage verbalization of questions—and guesses as to the answers—such as: How are you and a burning candle alike? Where in your body can oxygen combine with another substance? Where can the carbon in the carbon dioxide in your breath come from? How is the energy released useful to you? If children mention cells, what is a cell? How can you tell a living cell from a molecule? What must a cell do to stay alive? Several life processes will be mentioned. As soon as all ideas have been volunteered, let the children proceed to investigate, through the sections of their text, how the cell is a mechanism for the interchange of matter and energy in the environment.

Section 1: A CELL AT WORK

(*Text pages 146–149*)

SUBCONCEPT

Cells interchange matter and ener with the environment.

Processes emphasized

- Discussion
- Observation
- Model making
- Hypothesizing
- Investigation

Children observe that the yeast cell, a tiny living thing, gets its energy from the food it uses.

Introducing the Concept

Stimulate thinking and discussion by asking: 1. What one reason could you give for these three questions? Why do we eat? Why do animals eat? Why do plants make food for themselves and animals? (For *energy* to grow and work.) 2. Name the smallest living things you can think of. (List on board.)

Would each of these need food for energy to grow and do work?

Help children see that key words in (1) and (2) are *energy* and *living things*. You may now wish to have them read text page 146 in preparation for the investigation.

Developing the Concept

Children fix the understanding that living things can grow and can reproduce.

Equipment and Materials

- . . . modeling clay
- . . . yeast
- . . . cotton string
- . . . cover glass

The yeast plant. Introduce a class discussion about the yeast plant. Yeast grows by budding—buds bulging from the parent cell and forming a chain much like soap bubbles at the end of a pipe or tube. As the cells enlarge, they break off and presently start their own chains of bulging buds. The timing of this process can be anticipated after due observation. Provide ample modeling clay for children to make the budding yeast model described in the text.

You may wish to use yeast cells, which may be kept moist for observation by means of a cotton string or wick. Drape the string around one edge of a cover glass. Have the string lead into a saucer of water. After a little practice, the child who demonstrates this investigation can predict and announce to his classmates the moment to observe budding.

Through investigation, children infer that a yeast cell gets energy for growth from sugar.

Equipment and Materials

- . . . squares of black construction paper
- . . . pulverized yeast

(See also Teacher's Manual for *Classroom Laboratory 5.*)

Energy for growth. Pass around squares of black construction paper folded to make a shallow tray. Scatter some pulverized yeast in each tray. Encourage thoughtful discussion by presenting these questions: What do you think is in the trays? (Have children smell and feel the yeast to help them identify it.) Is it alive or nonliving? (Children may suggest planting the yeast to find out if it is a living thing.) If the yeast is living, what would it need for energy and growth? (Food.) Suggest choosing a quick-energy type of food. If you are tired after exercising, such as doing push-ups, would you go for lettuce leaves or an ice-cream cone? (Ice cream.) Why? (Sugar content—quick energy.)

Let's try giving quick-energy food to yeast to make it grow. Refer children to the investigation on text page 147. After children have completed the investigation, you will want to write this equation on the board:

$$\text{sugar} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water}$$

To make sure children understand how yeast cells can break down sugar molecules, choose volunteers to explain the equation in terms of the investigation they have just completed.

Extending the Concept

Equipment and Materials

- . . . sugar
- . . . yeast
- . . . flour

What makes bread "rise"? Something in dough makes bread "rise." What is this something and how does it push up "the dough"? Help children recall, from the investigation on page 147, that yeast reacts with sugar to form carbon-dioxide gas.

Select a volunteer to mix a solution of sugar and yeast. Add a small amount of flour to make dough. After several hours, have the class observe what has happened to the dough. The dough will have risen. The carbon dioxide that was produced when the yeast combined with sugar has formed bubbles in the dough. These bubbles remain trapped as air holes and cause dough to rise.

Why can't you make bread just from yeast and sugar? This activity is more in the nature of true experimentation than many, and it has wide implications and possible collateral learnings. A child who likes to "mix" things is a natural here. However, the activity requires care and precision in measuring and recording as well as creative planning. Challenge a *team* of children to show why we need all the standard ingredients of bread. Vary as shown:

1	2	3	4	5	6	
flour	sugar	yeast	flour	flour	sugar	
water	water	water	sugar	yeast	yeast	etc.
			water	water	water	

Later, vary the amount of liquid or of the solid ingredients.

Equipment and Materials
. . . drawing paper

Class activities. 1. Provide drawing paper for the children to make pictures of yeast cells at work in rising dough. Encourage imagination as well as accuracy of representation. The drawings may be used for a classroom display. 2. Have the class decide from their text whether yeast cells are plant or animal. Find the name of one of the relatives of yeast, which you sometimes see in your backyard or at the grocery store. (Mushrooms.) Can the children name any other nongreen yeast cousins? (Fungi, mistletoe, dodder.)

(*Text pages 148–149*)

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. a 4. b

Using What You Know. 1. Oxygen. 2. Yeast reacts with sugar to form carbon-dioxide gas.

(*Text pages 149–152*)

SUBCONCEPT

Energy within a cell comes from a cycle of breaking down and building high energy containing molecules (the cell energy process).

Section 2: THE CELL'S ENERGY PROCESS

Children gain further understanding of the process of oxidation. They learn that as food substances are oxidized in the body, energy is produced.

Processes emphasized
- Observation
- Library research
- Analysis of data
- Hypothesizing
- Theorizing

Introducing the Concept

We say our energy to go and grow comes from food. Just how does this happen? In order to understand, shall we consider some other energy machines which go even if they don't grow? You say gasoline makes your car go. Just gasoline all by itself?

Elicit from the children the idea of air for combustion and spark for ignition or kindling. How do we get air into our cells' energy machine? (By breathing.) How do we get food into our cells? (By making food small enough to be dissolved and moved through cell membranes.)

What happens next in our cells? Encourage children to read the text very carefully. Then ask:

Can you think what the two big ideas in this section are? (Oxidation and the cell energy cycle.)

Developing the Concept

Children develop insight into combustion as analogous to certain kinds of oxidation—fast or slow.

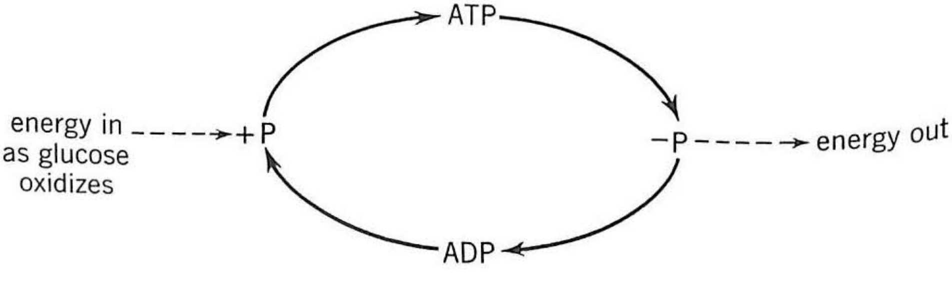
What is oxidation, anyway? Which of these four illustrate oxidation: a burning candle, rusted metal, weathered rock, rotting wood? Elicit a definition of oxidation. Encourage children to consult the text for answers to these questions. Which example illustrates rapid oxidation? (The candle.) Which ones illustrate slow oxidation? (The wood, metal, and rock.) Call on volunteers to write on the board two equations to show what happens inside our cell energy machine. (See text, page 150.)

You will want to encourage children to use correct terminology in science as far as possible. As the text states, *oxidation* occurs when substances combine with *oxygen.* Compare the terms as a means of clarifying the relationship. Help children distinguish between oxidation and burning. *Burning* is not appropriate to describe energy released in cells for several reasons. Body temperatures are lower than those at which burning occurs. How hot does your body machine run? (98.6° F.) How hot is a gas flame? (Sufficient to boil water at 212° F.) A burning log or candle releases light and heat. Cell energy produces some heat, seldom produces light. An exception is found in the light energy given off by fireflies.

Children increase insight, gained in Unit One, into energy as a cyclical process—all within a tiny cell.

The huge molecules which power the cell energy cycle. Refer children to page 151 of the text. The three letters ATP stand for the name of the huge molecule which is the cell's energy machine. Inquire if children can figure out the meaning of each letter. A = Adenosine, T = Tri, P = Phosphate. The Tri tells us that the molecule has three parts of phosphate.

You know how a log is broken into smaller pieces (ashes) as some of its energy is taken out by burning. Likewise, as the cell uses some of the ATP molecule, there is less phosphate ($ATP - P \longrightarrow ADP$). Have children recall the equation for this change. What do these letters ($ADP + P$) stand for? (Adenosine diphosphate + a phosphate part.)



Now that children understand what these names mean and how a molecule breaks down or builds up, suggest they make a drawing or diagram to show this energy merry-go-round. Just as a hint, make a circle showing ATP at the top, and ADP opposite. Show energy leaving as ATP breaks down. The other half of the cycle should show the build up from ADP + P as the cell oxidizes glucose from food in solution.

Extending the Concept

Smokeless burning. Encourage children who like poetry to read Robert Frost's poem "The Woodpile." Ask how the line, "The slow smokeless burning of decay" applies to this section of text. Elicit ideas of ways to present the poem and its symbolism to the class.

Equipment and Materials

. . . steel wool
. . . jar
. . . saucer

Is rusting a form of slow or rapid combustion? The question may be answered as follows: Stuff a wad of steel wool or metal scouring pad into a jar which has been rinsed and is still damp inside. Invert the jar in a dry saucer. After a few days, the metal should be rusty. Encourage the observation and collection of other examples of oxidation, e.g., a weathered shingle, oxidized copper trim.

Reading and thinking. Suppose you want to conserve cell energy for a long journey in space. Can you think of ways in which plants and animals conserve energy? What happens to plants in winter when their food and water is locked up by frost? (They become dormant.) Leaf fall reduces water loss and general cell activity.

Encourage children to find out whatever they can about hibernation. Bears have large appetites and large heat-radiating body surfaces. How do they adapt to change of season? (They hibernate.) Can you name some of "The Seven Sleepers" of Indian legend—animals that hibernate? (Bears, woodchucks, chipmunks, turtles.) In case the children read about estivation, help them to realize that in such examples the dormancy is an adaptation to reduce water use by the cells.

(Text page 152)

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. a

Using What You Know. 1. ADP. 2. P. 3. glucose.

(Text pages 153–159)

SUBCONCEPT
Plant and animal cells have basically similar structures.

Section 3: GETTING INSIDE A CELL

Children see unity within diversity among cells. They gain a foundation of understanding for the process of diffusion of substances through a membrane.

Introducing the Concept

Review the children's understanding of the cell's "energy-machine" cycle as described in Section 2. Then ask the questions on page T–78.

Equipment and Materials

See text page 154; also the Teacher's Manual for *Classroom Laboratory* 5.

Does this cycle go on in animal cells as well as in yeast cells? Are plant and animal cells alike? Are all of our body cells alike? Does a cell have a mouth to take in food?

Encourage children to state their ideas before performing the investigation (page 154) which starts their discovery of answers.

Children begin to understand that the cell membrane delimits the cell as a functioning unit.

Processes emphasized

Investigation (with design of experiment)
Model making
Observation
Analysis of data
Hypothesizing
Use of tools
Invention
Prediction

Equipment and Materials

. . . raw eggs
. . . plain glass or white saucer

Developing the Concept

Moving through a membrane. After the investigation, let the children read the text and tell you how many times they find the term *membrane* occurring in their reading. What is a membrane? Are there any clues from the context, the words which you find with the term? The repetition of *through* suggests that substances can move through membranes. Would you think that membranes might be thick or thin? (Thin.) Where is the membrane in a cell? (Surrounding it.) If we open a large cell such as an egg, can we see the membrane? (Yes.)

As one child examines the egg membrane and reports his findings to the class, another child might draw on the board what he sees. Enlist class attention for labeling the parts: the egg nucleus (the white spot near the middle of the surface of the yolk); the cytoplasm (the yolk and white of the egg). See page 153, where the terms *nucleus, cytoplasm,* and *membrane* are introduced. At two opposite ends of the yolk may be seen twisted threads much like those in the egg white nucleus. These threads act like a hammock string to hold the developing baby chick suspended in place. Just under the brittle outer shell the children can see the paper-thin membrane. What would need to pass through this membrane for the hatching chick to live? (Air.)

Children, through models, gain a better idea of cell structure.

Equipment and Materials

. . . plastic bags
. . . Saran wrap
. . . plastic jelly jars
. . . dry split peas
. . . cork

(See text pages 156 and 158; also the Teacher's Manual for *Classroom Laboratory* 5.)

Models of plant and animal cells. After the children have discussed their "before and after" concept of body cells (while reading the text), you may wish to invite them to set up cell models.

Beforehand, from local eating establishments, you and the children may have been able to collect individual plastic jelly containers. If possible, provide enough containers for children to work in twos or threes. Otherwise, supplement with the smallest sized plastic vegetable bags.

Encourage the children to construct models of plant or animal cells, or both. For example, a jelly jar with water (cytoplasm), split peas (chloroplasts), cork fragment (nucleus), and Saran wrap (membrane) could represent a model plant cell. Be sure that children understand all models are much bigger than actual cells. An average cell is so small that it would require 2,500 side by side to cover an inch-long line. You may wish to dramatize this relationship by an inch line on the board. Invite volunteers to put as many dots as possible on an inch line.

Children derive insight into diffusion as a basic process in all bodies, especially cells.

Analyzing observation. How do solutions pass through a sealed cell? Recall with children that a cell must be sealed into or bounded by a membrane in order to be a cell; that only food in liquid form or solution can pass through cell membranes. How does this happen?

Fill one test tube with thin starch paste to represent liquid cytoplasm within the cell. Cover with wet filter paper or porous cellophane to represent the membrane. Fill a tumbler half full of $\frac{1}{3}$ dilute iodine solution. Ordinary household iodine may be diluted with water. The children may later find interest in observing effects of different dilutions of iodine. How can we tell if iodine is moving through the membrane? (The starch paste will begin to turn bluish.) A few children may wish to continue the investigation by trying other materials as membranes, other materials in solution. For example, if iodine is used in the test tube, starch solution in the tumbler, the children can see the iodine move through the membrane in either direction. Starch does not move through the membrane because it does not dissolve (is insoluble). The observation may be recalled when the text, page 196, introduces the role of saliva in digestion of starches.

Equipment and Materials

. . . test tubes
. . . corn starch
. . . iodine
. . . tumbler
. . . filter paper
. . . filter paper or porous cellophane
. . . paper towel

Extending the Concept

Using a microscope. This section introduces children to animal cells. Superficially, plant and animal cells appear to have little in common. If at all possible, solicit the advice and participation of the school nurse or doctor in securing slides showing blood cells ("blood smears") or slides of other animal cells and tissues. Trained medical personnel will have the skill and authorization to proceed in making blood smears on the spot. Children will be anxious to see how their own blood cells appear under a microscope. Check with the school principal to find out if there are parents who, for any reason, might not wish their children to participate.

Gases through a membrane. Do gases such as air pass through membranes? Using what you know about the relative closeness of molecules in air and in liquids, would you predict gases would move through membranes? (Yes.) Recall the air space at the larger end of an egg. Children may have observed in opening eggs that this space is separated from the egg contents by the membrane. (See above, Developing the Concept.)

Equipment and Materials

. . . phenolphthalein
. . . test tube or tall jar
. . . bottle of household ammonia
. . . filter paper

The diffusion of gas through a membrane can be dramatically shown as follows: Wet some paper toweling with phenolphthalein solution. (See *A Sourcebook for the Biological Sciences*, page 406.) Stuff the toweling into the bottom of a large test tube or slender olive jar. If phenolphthalein is not available through your druggist, try a solution of rubbing alcohol and pink laxative tablets containing phenolphthalein. Cover the test tube or bottle with membrane material and invert over a bottle of ammonia. What causes the rapid reddening of the paper toweling? The ammonia fumes diffusing through a membrane react with the phenolphthalein to produce the red color.

(Text page 159)

Reviewing the Concept

Before You Go On. A. 1. b 2. b **B.** Children should show an understanding of diffusion as a basic process.

Using What You Know. 1. a. cytoplasm; **b.** cell membrane; **c.** nucleus. 2. Glucose; it will pass through a membrane.

(*Text pages 160–163*)

SUBCONCEPT
Cells are specialized for different functions.

Processes emphasized
Observation (and analysis)
Investigation (with design of models)
Hypothesizing
Prediction
Uses of tools

Section 4: CELLS IN A PLANT

Children are introduced to some of the interesting cell structures found only in plants (e.g., chloroplasts, cellulose, root hairs).

Introducing the Concept

Hold up a piece of paper. Ask children if they think it is a product of a plant or animal. (Plant.) Let children hypothesize briefly. Is any part of the plant cell left when the paper is burned? (Cell wall.) Set fire to the piece of paper. For safety, the paper may be held with tongs above a sheet of kitchen foil. Turn to the text to verify the results. You may wish to lead into the lesson with these questions:

What holds up your cells? (Your skeleton, cartilage.) **What holds up a plant?**

Developing the Concept

Children infer that cell walls support and stiffen the structure of plants.

Differences in plants and animal cells. After children read the text of the section, clarify the differences between plant and animal cells, especially with regard to the cell exterior. Both plant and animal cells have membranes, but in plant cells the membranes lie so close to the cell wall as to be almost indistinguishable. Animal cells do not have cell walls (text page 155).

Show pictures of various plants and animals and ask the children to designate which would have cells with cellulose cell walls and which would not. Try matching stylized cell drawings with pictures of plants and animals.

As primitive plants developed stiffer cell walls, they grew taller.

The need for a cell wall. The investigation suggested for this section (text page 162) may well be started several days in advance by a team of young science assistants.

If time permits, you may wish to review the appearance and character of yeast cells (Section 1). Recall that yeast is a nongreen plant. List other nongreen plants. In a second column list green plants. Now ask for the largest in each group. The children should readily see that the nongreens as a group are not so large as to need the internal stiffening that is necessary in a tall weed, a shrub, or a tree. The more primitive plants have less cellulose in the cell walls.

Encourage children to make diagrams for their science picture dictionary for such terms as *cellulose, cell wall, nucleus, chloroplasts, cytoplasm, membrane.*

Select a few to post on the science bulletin board.

Extending the Concept

Plant air conditioning and humidity control. Children with access to a microscope can have the experience of seeing for themselves the special cells which let in carbon dioxide through layers of thickened covering cells.

Equipment and Materials

- . . . geranium or kalanchoe
- . . . razor
- . . . medicine dropper
- . . . glass slide
- . . . microscope

It is generally thought (though the evidence is not all in) that the *guard cells* also open or close, thus regulating the plant's internal moisture content. Use a razor to peel off the thinnest possible piece of skin from under a geranium or kalanchoe leaf. Place the leaf in a drop of water on a glass slide. Under magnification the *stomata* (Greek, meaning "little mouths") can be seen. The two halves together look somewhat like eyes. In dry or hot weather the guard cells close slightly in order to reduce water loss.

You may wish to let the children find the reason why there are few or no stomata on the top of the leaf. (On the top they would be exposed to the hot sun and could become clogged with dirt and debris.)

Where would you find the stomata on a lily pad? (On top; otherwise the leaves would drown as their air spaces filled with water.) For further observations and activities with regard to guard cells see pages 65–66, *A Sourcebook for Elementary Science.*

Equipment and Materials

- . . . celery
- . . . food color
- . . . paring knife

Conducting tubes in plants. Many children have tried putting celery in solutions of vegetable dye. For review and extension, let them place a stalk of celery with leaves attached in a half glass of water colored with about ten drops of food coloring. Let stand overnight. The leaves will have red markings showing the path of the solution. A "string" pulled out of the celery stalk will be red also. A cross section of the stem will show red dots. Lead the children to infer that these red dots show the location of the food-and-water-conducting tissue in celery plants. For further investigations see pages 66–88, *A Sourcebook for Elementary Science.*

Equipment and Materials

- . . . tree cross-section showing annual rings
- . . . cross-section of growing tree showing cambium layer

How does a tree grow larger? Children may recall stages of insect metamorphosis from earlier work. Some may have seen examples of split pupa cases or watched a moth emerge from a cocoon. How does a tree keep on growing without splitting its bark? It should be evident that bark and similar thick outer-covering cells keep plants from drying out. A cross-section of a woody plant shows several kinds of plant tissue. See the layer of green tissue known as *cambium.*

In older tree cross-sections the wood rays radiating from the center indicate routes along which liquids move sideways; only the cells of the inner bark and outer part of the wood (the cambium) are alive. The rest of the wood and bark is made of dead cell walls. The whole subject of annual rings in trees as it relates to cell structure is worth further study. Encourage interested children to read and report, using diagrams or actual examples.

(Text page 163)

Reviewing the Concept

Before You Go On. A. Plant and animal cells both have a nucleus, cytoplasm, and a cell membrane. The plant cell has a cell wall; the animal cell does not.

Using What You Know. 1. Cell A underground; cell B above ground, because it has chloroplasts. 2. Cell walls.

(Text pages 164–167)

SUBCONCEPT
Cells reproduce themselves.

Processes emphasized

Use and analysis of data
Measurement
Hypothesizing
Theorizing
Prediction
Investigation (design of models)

Section 5: A WHOLE SKIN

Children see for themselves that cell division is rapid and prodigious.

Introducing the Concept

Ask someone to exhibit a recent cut or scratch. Have you had other external injuries? Why don't they show now? What do we really mean when we say a cut has *healed?* Here is a cloth which has been ripped. We can mend or patch it, but can we *heal* it? Is there a special cell function which explains healing? You may wish to leave this and the preceding questions unanswered, or only answered in part, until the children have read the section.

How does a whole skin grow from one skin cell?

When cells divide, each new cell has its own nucleus.

Equipment and Materials

. . . plastic bags
. . . colored water
. . . bits of cork
. . . small boxes
. . . modeling clay

Developing the Concept

The need for a nucleus. Suspend in full view two clear plastic bags of colored water. One contains a cork to represent the nucleus; one does not. Present the two plastic bags, one of which could be a model for *new* skin cells. Can you decide which model represents a new cell?

Would you use plastic bags or small boxes to make models of plant cells? (Boxes.) The children will recall from Section 1 of this unit that yeast, which is a plant, reproduces by budding. Modeling clay is helpful in showing the process of budding. It is true there are differences between single- and multi-celled organisms. For the elementary grades it is important only that children realize that cell division also entails division of the nucleus. Read the text and perform the investigation.

Children perceive that cell division takes place by continual doubling.

Multiplication or division? You remember, text page 155, that there are millions upon millions of cells in your body—actually about thirty trillion. How long does it take to make thirty trillion cells from one cell? Make a diagram on the board to represent one complete cell. Show the two daughter cells which result after cell division. Each of these two cells redivides and the total is four. Repeat with drawing or other illustration to indicate the continual doubling in cell division. Shall we call the splitting of cells *multiplication* or *division?* (Really both.)

Why do you grow bigger? Does each of your tiny cells grow big—like a balloon? These questions may clarify that growth is due to cell division, not enlargement.

For one kind of plant cell (bacterium), cell division takes about twenty minutes. You may wish to ask the children to complete the chart to discover how many bacteria there could be at the end of a day.

Time	Number of Single-celled Organisms
0 minutes	1
20 minutes	2
60 minutes (1 hour)	8
1 hour 40 minutes	32

Once you are grown, do your cells keep dividing? (Yes; for release of energy and replacement of worn-out cells.) Clarify with children the understanding that in both plants and animals cell division continues as long as the organism is alive (text page 167).

Extending the Concept

Do you grow all over or do parts of you grow at different rates? School health texts and school health personnel can help children answer this question.

Equipment and Materials

- . . . sprouting onions or other bulbs
- . . . corn or bamboo shoots
- . . . waterproof ink
- . . . Easter lily pollen
- . . . sugar

To demonstrate that parts of an organism do not all grow at the same rate, mark the sprouting tips of grasses, lilies (bulbs), or other parallel-veined leaf plants. Use fine calibrations, as $\frac{1}{8}''$ or $\frac{1}{16}''$, to mark off an inch or two from the tip down. Waterproof India ink does not run or blur. Within a few days the children can see that the markings at the tip have spread further than those closer to the base; i.e., the most rapid cell division takes place at the tip of a leaf. Net-veined leaf growth is similar but shows a less striking change.

Roots also show differential growth rate. For further details see page 110, *A Sourcebook for the Biological Sciences.*

Easter lily pollen in sugar water will grow pollen tubes large enough to be seen without magnification. One group of pupils had a rich experience in studying the growth rate.

Cell models. Foster creative suggestions for models of cell division, both plant and animal. The children should show (text pages 164–165) that animal cells divide by pinching in; plant cells by building a new cell wall. The nucleus must split in two (fission), and each new cell must have its own nucleus.

(Text page 167)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. b 4. b

Section 6: JUST ONE CELL

(Text pages 168–172)

SUBCONCEPT

A single-celled organism performs all the life functions within the cell; a many-celled organism is a community of interdependent cells.

Children have been introduced in previous sections to the single cells which make up common plants and animals. This section introduces the strange new world of micro-organisms—single-celled plants and animals.

Introducing the Concept

Equipment and Materials

- . . . aquarium
- . . . drinking straw or glass pipettes
- . . . medicine dropper
- . . . glass slide
- . . . microscope

Have you ever looked at stars in the night sky? What difference would it make to look through a telescope? (You would see many more stars; they would look larger.) Can you name another instrument which helps us look at things we cannot see, and also see them larger. (A microscope.)

If it is possible to secure a somewhat "murky" established aquarium, exhibit and ask the children: What do you see? (Fish, plants, water.) If we withdraw a drop of water from close to the bottom, we might name it, "World in a Drop of Water." How could we prove this title describes our drop of water?

Is there invisible life in a drop of water?

Developing the Concept

Children plan for collecting, culturing, and studying protozoans.

Invisible life in a pond. When children finish reading the text of the first three paragraphs, you may wish to make plans with them for collecting pond or ditch water. For safety, insist on plastic rather than glass containers.

Processes emphasized

Observation
Field trip
Investigation (with analysis of observations)
Discussion
Reading
Uses of tools
Library research

A protozoa farm. Planning should include provision for the culture materials. It may help the children if you develop very briefly the idea of food chains. With the aid of simple blackboard diagrams, illustrate microscopic plant life (bacteria) as the first link in a chain of water life, each larger form dependent upon the lower forms.

Should we keep our jar in sun or shade? Why shade? The reasons will be given more fully in *Concepts in Science 6.* For the present you may wish merely to make children aware of sunlight as a factor that slows down or stops bacterial growth. For further details on collecting and keeping pond life, see page 73 of *A Sourcebook for Elementary Science.*

Protozoans move and gather food in different ways.

Equipment and Materials
See text page 170; also the Teacher's Manual for *Classroom Laboratory 5.*

The many motions of protozoans. You are now ready for the investigation on text page 170. As a guide to pronunciation and identification you may wish to ask the children to say with you the names of the four protozoans described on text page 169. Invite volunteers to demonstrate the movements of each protozoan if they can find one, while the other children identify by checking the text. When do you move about in a way like the paramecium? (When you are swimming.) The same scientific law or principle that explains how you and the paramecium move through the water also explains how rockets are lifted into the air. Can you name the law and perhaps state it? (Newton's action-reaction principle; see page 104, Unit Three.)

Children build a foundation for understanding organization of cell structure for cell function within organisms.

One cell or many? How many kinds of cells are needed to carry on the work of your body? Unit Five, Section 3, develops this information in detail. For the present you may wish to seed thinking only to the extent of bringing out the idea of organization for living (text page 171). What advantages are there to being a many-celled organism, having groups of cells doing different jobs? Would you rather be a paramecium or a mouse? Why? Which organism can do more work?

Extending the Concept

Equipment and Materials
. . . cotton
. . . medicine dropper

Cell division—seeing for yourself. As an extension of the preceding as well as the present section, you may wish to assist children in looking for a paramecium or ameba in the process of cell division. It may help to lay a few thin wisps or strands of absorbent cotton across the clean slide. The cotton tends to confine the more active protozoans. A medicine dropper or drinking straw used as a pipette can be used to withdraw from near the bottom of the container water most likely to contain protozoans. This method helps you not to stir up the rich bottom ooze or sediments.

What's in a name—if it's protozoa? Children who like to read may be challenged to find the true meaning of the term *protozoan* and its relationship to geological periods and to fossil evidence of life. (*Proto,* first; *zoion,* animal.)

Another interesting topic for inquiry is the derivation of little ameba's full name, *A. Proteus.* Why does the classical description of the god Proteus fit the little ameba so well?

Exploration of the micro-world. What is the difference between a telescope and a microscope? Children with interest in optics or history may find pleasure and profit in reading Leeuwenhoek's own descriptions of the world he discovered through the first microscope. If you have on your science reading table *Wonders Under a Microscope* by Margaret Cosgrove, refer children to Chapter 4, "Discovery of a Continent."

(*Text page 172*)

Reviewing the Concept

Before You Go On. 1. A single-celled animal is a complete organism (one cell). A single animal cell is only part of an organism of many cells. The single-celled animal carries on all life activities in one cell. A single animal cell is dependent on other cells for food, movement, and other life activities. 2. Have children consult the text, page 171, for these differences.

Using What You Know. 1. *Muscle cell*—part of an organism; *Vorticella*—a complete organism. 2. They are different. Consult the text and the answers to "Before You Go On."

(*Text pages 172–176*)

SUBCONCEPT
The pattern of the organism
passed along to new cells by dup
cation of chromosomes and th
DNA content.

Section 7: LIKE BEGETS LIKE

Children become aware of the concepts underlying cell reproduction and continuation of species. Children learn that one cell can divide and makes two microorganisms or can continue to divide and "grow." In either case the chromosomes within the nucleus set the pattern of unity within diversity.

Processes emphasized

Observation
Invention (models)
Analysis of observations
Discussion
Inference
Prediction
Theorizing

Introducing the Concept

Your dog or cat looks like its parents. Why? (Because of cell division.) Let's recall what we have learned about cell division. Could you draw on the board a diagram showing cell division in a protozoan? Are the daughter cells more like the parent than they are different? (Like.) After the drawing has been studied, ask: What differences do you see between yeast buds and protozoan cells? (Buds do not duplicate the parent cells.)

***Fission* means splitting into equal parts. Yeast and paramecium cells are dividing. To which one does the term fission apply?**

Children visualize how chromosomes duplicate in cell division.

Developing the Concept

Setting the pattern—styles in earthworms. After the children have read the section, you may wish to continue as follows. Ask the children each to draw an example of cell division showing a rather large nucleus in each daughter cell. Since earthworms have two large chromosomes, ask children to suggest two characteristics of earthworms they have seen, e.g., (1) fat, (2) brown. Decide on a color code for each of these traits. Draw and color a body in the mother cell to correspond. Draw two daughter cells and show smaller, colored bodies to represent duplicated chromosomes.

Each kind of animal has its own pattern of cell chromosome count. How many chromosomes would you find in each cell of a vinegar fly? (8) A paramecium? (16) A human being? (46) A crayfish? (200+) Encourage children to think of ways of representing duplication of chromosomes during cell division in any of the above organisms.

Children conceptualize chromosome pairing by making and manipulating models.

Chromosomes go in pairs (twins). Recall the text definition of fission. Do yeast cells divide by fission? (No.) Ameba cells? (Yes.) Mouse cells? (Yes.) To understand how chromosomes duplicate during fission, let us make and study a model (figure on page 162, *A Sourcebook for the Biological Sciences*).

Equipment and Materials

- . . . double-stranded insulated wire or TV lead-in wire
- . . . pliers or scissors
- . . . string
- . . . lacquer paint
- . . . paring knife

For a total activity, the following will go more smoothly if you or some volunteers prepare (and practice) the illustration ahead of time. Make clear the purpose of the activity. Organize the children to work in twos or threes. Short 3″–6″ lengths of wire suffice. Lacquer one half one color, and call it the X-chromosome. Lacquer the other half another color and call it the Y-chromosome. A paring knife may be safer than a razor to separate the insulated wires at midsection. Tie short strings to each piece of wire at midpoint. Slip a rubber band through the strings around the wire. Pull the strings apart slowly, as in cell division. As the wire splits in two, much as chromosomes are drawn out in cell division, call attention to the fact that each wire chromosome has now become twins. Be sure children understand it is the substance DNA *within* the chromosome that duplicates itself.

Extending the Concept

DNA—the amazing substance within chromosomes. Where within a cell do you find DNA? What do the letters mean? (*D*eoxyribo*N*ucleic *A*cid.) Some children, from older brothers or sisters or through local pet stores, may secure paper models of DNA. These models make attractive mobiles in the classroom. Although the complicated bonding and pairing of substances within DNA lie beyond the comprehension of elementary-grade children, the model itself seeds the idea of complex molecular structure discovered within the tiniest cell.

Using Spallanzani's techniques (methods). Children with access to microscopes may try to demonstrate Spallanzani's feat of isolating single organisms from a culture medium. Some children may prefer to read and report on Spallanzani's work.

(Text pages 175–176)

Reviewing the Concept

Before You Go On. A. 1. b 2. b 3. b 4. a

Using What You Know. 1. In budding, a new cell grows from a parent cell; in *fission*, the parent cell divides into two cells. 2. 1024. 3. A yeast cell buds and forms a new yeast cell; a paramecium divides into two paramecia; a robin's egg develops into a robin.

(Text pages 176–181)

SUBCONCEPT
Growth in a many-celled organism consists in multiplication and differentiation of cells.

Section 8: FROM ONE CELL

How does a single egg cell produce many different cells? Through investigation, children follow the stages in developing frog eggs. The development of warm-blooded animals (robins and cats) is traced from egg to adult.

Introducing the Concept

Display a hard-boiled egg yolk in front of the class. What kind of cell is this? (Chicken egg cell.) What kinds of cells may be formed from a fertilized egg cell as the chicken grows? Catalyze thinking by starting to list on the board, for example—feather cells, skin cells, and others.

Paramecia, frogs, robins, and kittens all start growing from a single egg cell. Which kind has the best chance of growing into a complete organism?

Growth of organisms from egg to adult provides many examples of adaptive change and development.

Developing the Concept

Follow-up questions. The investigation into the growth of a frog is a long-term project. It is best, therefore, to let the children read the text for this section before discussion. The following questions based on the text may be used either for written or oral follow-up:

What is your normal internal heat? (98.6° F.) You discover a frog while walking outdoors. What would the frog's normal temperature be? (Outdoor air temperature.) If you have a pet turtle, ask your parents' or teacher's help in taking its temperature. Which has a better chance for growth, the egg cell of a cat or the egg cell of a robin? (Cat.) Why? (Protection within the mother's body; even temperature.) Can you explain the need for fish and frogs to lay so many eggs, while a bird lays only one egg at a time? (Fish and frog eggs are not protected by the parents as most birds' eggs are.)

Note to Teacher: In planning for the investigation, page 177, you may need to consider an alternative to using frog eggs. One alternative could be using live fish eggs. These should be available through a local aquarium, pet store, or fish hatchery. With either frog or fish eggs, op-

Equipment and Materials

. . . a jar of salmon eggs

(See text page 177; also the Teacher's Manual for *Classroom Laboratory* 5.)

portunity is given to see the development of a new organism from an egg.

Body temperature and life activities. What is a frog's temperature in relation to yours? (It varies with the surroundings.) What is a bird's temperature? (Text page 179.) How is your temperature more like a bird's? (Even though the bird's temperature is higher, it is regular like ours.) What are some advantages of a regular, warm temperature? *Clues:* What does a frog (a cold-blooded animal) do in the winter? (It is not active.) Are birds inactive in the winter? (No.) Are you? (No.) Birds and you can carry on activities in all seasons because a fairly even temperature means you don't have to slow down; a frog does. Temperature of the body cells seems to be related to oxidation of food. Recall that food is needed for energy. Reproduction is a life activity. What protection is given to the unborn young in a warm-blooded animal? (Care of the eggs by the warmth of the parent birds; growth of the developing young inside the mammal.) The rate of oxidation of food seems to have an effect on the carrying on of life activities, and the rate seems to be fairly constant in birds and mammals.

Children infer that environmental conditions affect the development of an organism.

Processes emphasized

- Planning a project
- Investigation (extended)
- Measurement
- Hypothesizing
- Model making (invention)
- Library research
- Uses of tools

Extending the Concept

Food supply for developing embryos. Soak lima bean seeds until the seed coats slip off easily. Remove the two cotyledons. The cotyledons serve the same function in a plant as the yolk and white of a hen's egg. What could this function be? (Energy and food supply for rapid cell division in developing embryos.) To clarify the understanding, help the children find the tiny embryo lying between the cotyledons. Make the same examination of corn seeds.

Equipment and Materials

. . . lima bean seeds

How good are you at nest-building? If an empty robin's nest is available, take it apart, list the contents, and sort into small boxes or paper trays. Now try rebuilding the nest. If an empty nest is not to be found, let children suggest and bring in materials such as those listed.

Equipment and Materials

. . . old robin's nest
. . . sticks
. . . bits of string
. . . hair
. . . mud
. . . leaves
. . . small boxes

Reading enrichment. Children who enjoy exploring books may enlist the help of school or public librarians to help them find "egg" stories such as Roy Andrews' discovery of dinosaur eggs in the Gobi desert. "Turtle Eggs for Agassiz" by Dallas Lore Sharp is a short classic which is worth reading aloud. It has been reprinted by the *Reader's Digest* in the April, 1941 issue. It has also been adapted, under the title "Turtle Eggs on the Run," for their Reading Skill Builder series, Grade 3, Part Two, 1959.

Microscopic studies. Children with access to high-power microscopes may be sparked by the class study to examine and illustrate "spores," the primitive means of continuing plant species before seed plants developed. Collect spores from spore cases on the underside of fern fronds. A city child may study spores, or a spore print, from hothouse mushrooms. For details, see *A Sourcebook for Elementary Science*, pages 67–68.

Reviewing the Concept

(Text pages 180–181)

Before You Go On. A. 1. b 2. a 3. a 4. b

Section 9: FROM EARTH INTO CELL

(Text pages 181–184)

SUBCONCEPT

Protoplasm, the living material in the cell, is composed of elements and compounds in the Earth's crust and atmosphere. (There is a flow of matter and energy between the organism and the environment.)

Children gain deeper insight into the complex chemistry of a living cell. They investigate the compounds in protoplasm and discover that they are composed of common elements. Atoms are the building blocks of the cell's compounds.

Introducing the Concept

Your cells are built from materials in your food. Plants are built the same way. Your food comes from farm and market. What about plants?

What are plant food "markets"? What kind of "groceries" do plants use?

Developing the Concept

Children discover the distinction between cytoplasm and protoplasm.

Equipment and Materials

. . . hen's egg

(See text page 183; also the Teacher's Manual for *Classroom Laboratory* 5.)

Protoplasm and cytoplasm. After children have had opportunity to read the text as far as the cue to the investigation on text page 182, explore their thinking. Of the three parts of cells we learned about in Section 3, which one has a name most like protoplasm? (Cytoplasm.) Let us review by restudying a large cell—a hen's egg. Have children point out the nucleus (egg nucleus spot), the cytoplasm (yolk and white), the membrane (encloses the yolk and white), and the protoplasm (all the living material). What compound of protoplasm begins with the same prefix? (Protein.)

Is there protoplasm in sprouting wheat seeds? (Yes.) Why? (The cells are living.) Would you think there would be more or less protein in wheat protoplasm than in feathers or hairs? How could you tell? Some answers lie in the investigation (text page 183).

Tests of foods give the children insight into the matter living things take from their environment.

Food testing. In planning testing procedures in the investigation, it may help to develop a wall chart with the children, as follows:

Tests for	Sample	Tests	Materials
Proteins	feather	smell	aluminum TV tray, matches, and candle
Carbohydrates	cereal flakes	water and carbon	aluminum TV tray, matches, chilled glass plate or mirror, and candle
Fats	peanut butter	grease spot	brown paper
Starches	bread potato	blue-black	diluted iodine
Minerals	feathers hair	ashy residue	TV tray, matches, and candle

Processes emphasized

Testing
Explaining
Recording of observations
Prediction
Inference
Hypothesizing
Theorizing
Model making

With the least encouragement children will want to test other foods and substances using methods suggested by their text. Encourage careful charting of procedures and observations. For additional suitable methods, see *A Sourcebook for Elementary Science*, pages 216–220.

Protoplasm contains common elements and compounds.

Elements and compounds of protoplasm. Children who indicated particular interest in Unit Two may wish to mine the text further, planning and executing a way of displaying the various elements in protoplasm.

What test you made uncovered the compound which makes up 99% of protoplasm? (Burning carbohydrates.)

Atoms and cells are each a kind of building block. Can you think of a way to illustrate or explain the difference?

Extending the Concept

Equipment and Materials
. . . household scales

How much of our food is water? Encourage children to weigh various foods before and after they have been heated or dried. The children may be challenged to use postal or druggist's scales with calibration and measures finer than those found on household scales. A study of the package labels of dried foods can be an interesting source of information regarding their water content.

Equipment and Materials
. . . half-gallon milk carton
. . . glass pane to fit
. . . corn or bean seeds

How do soil minerals enter a plant? When you burned feathers, hair, or wood, you obtained ashes which were largely minerals. Since animals eat plants, where in plants would you find gateways for the minerals to get into the plants? Children should recall roots and root hairs from Section 4 of this unit. They may wish to study their function further.

Lay a half-gallon milk carton on its side. Cut out most of one side and set in a piece of glass. Hold in place by filling with soil. Plant corn or bean seeds in a row near the glass front where you can watch development. Tape dark paper over the glass to keep roots from growing away from the light. Every day pull out a seedling and study the root structure.

You remember what you learned about membranes. The tiny root hairs with their thin, pliable walls come in direct contact with soil, water, and gases (mainly oxygen) between particles. Are root hairs necessary? Try transplanting seedlings from some of which the root hairs have been stripped.

(*Text page 184*)

Reviewing the Concept

Before You Go On. 1–3. Proteins (carbon, hydrogen, oxygen, nitrogen) mainly from animal products; carbohydrates (carbon, hydrogen, oxygen) from plants, as sugars and starches; fats (same elements as carbohydrates but combined differently) from plants and animals; minerals (many elements) from soil water; water (oxygen, hydrogen) free and from plants and animals.

Using What You Know. No; glucose has no strange smell, although both tests reduce substances to carbon. No; the test for fat will not work on sugar; the elements are combined differently.

Section 10: THE MAIN CONCEPT: CELLS AS BUILDING BLOCKS

(*Text pages 185–189*)

CONCEPTUAL SCHEME

A living thing is the product of its heredity and environment.

UNIT CONCEPT

The cell is the unit of structure and function; a living thing develops from a single cell.

Children review the concept that all living things are made up of cells. They clarify their understanding of each cell as an energy machine carrying out essential life activities. The concept of protoplasm as the physical basis of all life is reinforced.

CONCEPT SUMMARY

Rock or fossil? Someone brings you a piece of rock which he insists is a cross-section of a fossil palm root or dinosaur bone. How, with no more than a hand lens, could you verify his statement? If the material appears to have cellular pattern, it is likely to have been living matter. Cell structure, therefore, determines whether or not material was once alive.

How would you recognize a cell?

The term *cell* itself is an inept description. It was first used by Robert Hooke. One day, while observing a piece of cork through his crude microscope, Hooke noticed the cork appeared to be full of holes. Slice after slice showed the same pattern. In his famous book, *Micrographia,* published in 1665, Hooke called these holes *cells* because they reminded him of rows of cells, or bare rooms, in a monastery. Why do you think *cell* is a poor choice of words? Can you think of a better word? What are some of the things we know now about cells? (Cells are the fundamental unit of structure for all living things.)

Is it plant or animal material?

Plant or animal? A cell, the smallest unit of living material—like an atom, the smallest unit of a physical or biological substance—has a *nucleus.* Cells are contained within a membrane and, in a plant, also a cell wall. Someone gives you a prepared slide showing unidentified cells. Each nucleus is contained in a box-like space. Immediately you know you are looking at plant or animal cells. Which? (Plant.)

Why do plants have cell walls while animals do not?

Cell walls and skyscrapers. Why do you suppose plant cells have membranes plus cell walls while animal cells are enclosed only in a membrane? Most animal cells and tissues are supported by an internal bony skeleton or a more or less rigid external covering skeleton. Plant cells have to depend on the stiffening effect of many, many cell walls. In what way do cell walls serve as steel beams do in a big building? Next time you see a building going up, look closely at one of the steel beams or girders. In cross-section, the shape is exactly like that of capital letter I. You can see this also in bridge girders. This I shape offers the most strength for the weight the girders of the building or bridge will support. Now make a drawing of plant cells, such as onion skin, which you studied on page 160. Every intersection of the cell walls looks something like a capital I, doesn't it? Can you see why plant cells give so much support to the plant?

How are you built—from inside out?

How are you built? Have you ever watched a brick house being built, tier by tier? In some ways this is like the way your body is built; in some ways it is not. Can you think of some likenesses and differences?

Sometimes such a review is energized by dividing the class into teams, each team scoring a point for a reasonable answer. To discourage guessing, subtract two points for a thoughtless, ill-considered answer.

Your "house" has 30 trillion or more "bricks" or cells. What does this number tell you about the size of your cells? (Very small.) Even so small, your cells contain some tinier parts which make you what you are. Which of these cell parts makes you a boy or girl instead of an earthworm or a crayfish: your cell nuclei, your cytoplasm, your chromosomes, your cell membranes?

Your cells are alike and different. Is this a true statement? Encourage a review discussion which reemphasizes the cell parts that make up the building units of the body. Would the same kind of cells be suitable for your muscles and at the same time for your blood? Why not?

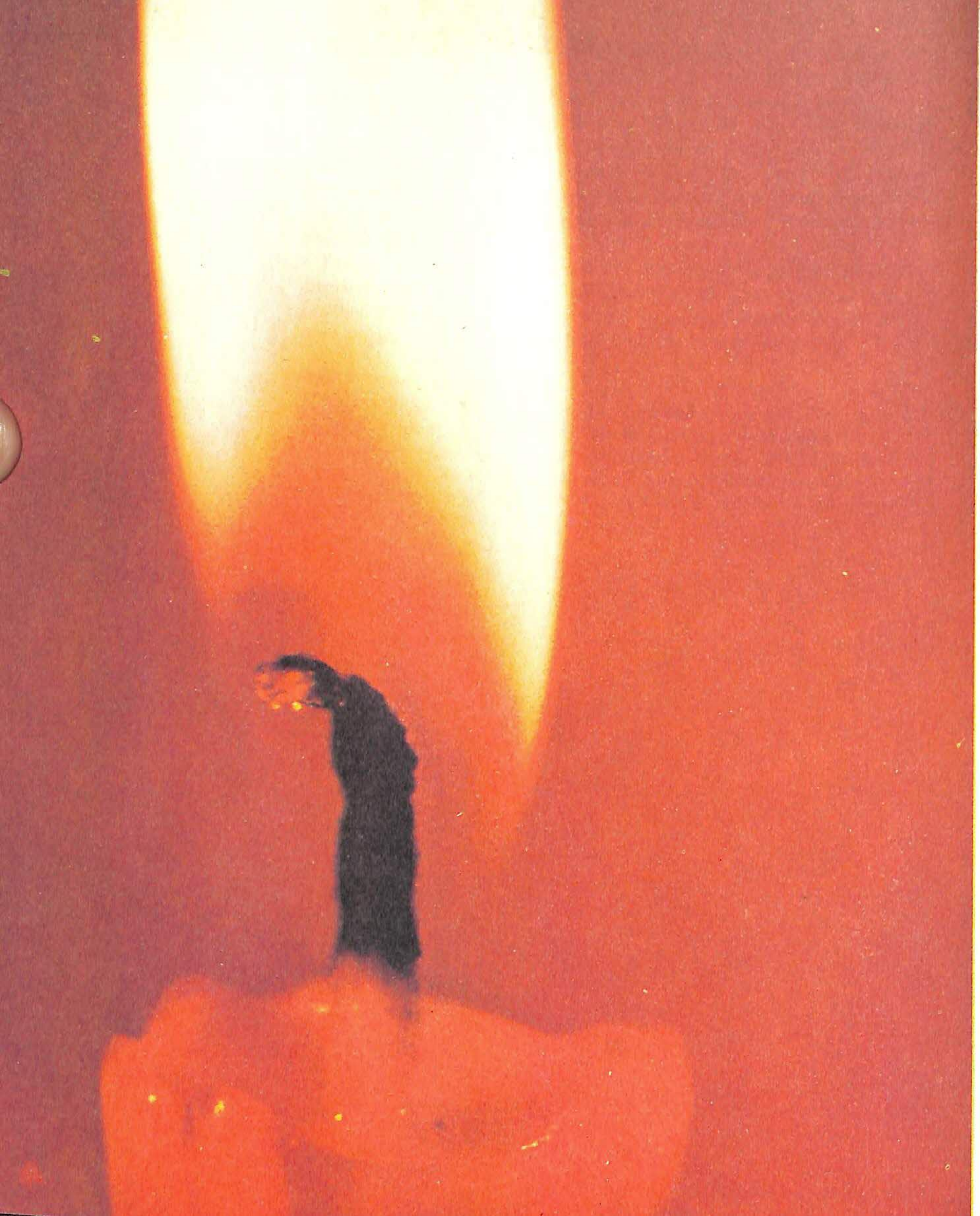
(Text pages 187–189)

FIXING THE MAIN CONCEPTS

A. **1.** The first two are plant cells; the other two are animal cells. **2. a.** The dividing cell shows no fission of the nucleus; there is no nucleus in one cell in the last stage. **b.** The nucleus divides in fission. **3.** Middle stage and last stage should show one rod-shaped and one hook-shaped chromosome on each side of the cell division. **4.** Carbon dioxide. If gas turns limewater milky, guess is correct.

B. 1. c **2.** c **3.** d **4.** a **5.** d

TEACHER'S NOTES



UNIT FOUR

BUILDING BLOCKS OF LIVING THINGS

Light a candle. Put a jar over it. The candle soon goes out. It can get no more oxygen from the air in the jar. To burn, a candle must have oxygen, as you know. The oxygen combines with substances in the candle as it burns. And the candle gives off, as it burns, carbon dioxide gas, water, heat energy, and light energy.

You too take in oxygen. You breathe out carbon dioxide gas and water. You give off heat energy.

Is it possible that a kind of burning produces carbon dioxide, water, and heat energy in your body? What kind of burning could it be, if it is burning? Where could it take place?

These questions have interested scientists for many years, and scientists have found some answers to them. Let's see what they have found out.

1. A Cell at Work

Food substances are used by all animals—by elephants and eels, cats and canaries, whales and mice. Food substances are used by all plants—maples and mosses, oats and orchids, geraniums and wheat, molds and all the plants of the sea. Food substances are used by your body.

Just where in a living thing are food substances used?

Let's investigate a simple living thing, about as simple a one as we can get. There is a very simple living thing that is easily obtained and kept alive. It is the yeast plant.

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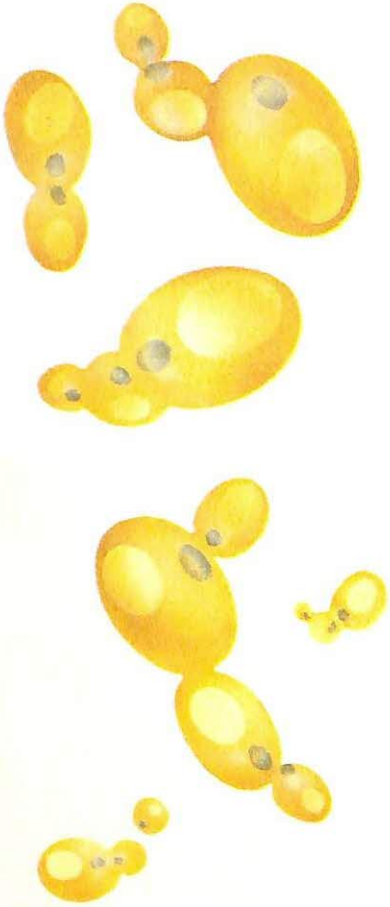


The Yeast Plant

Yeast is made up of millions of tiny yeast plants. Look at yeast under a microscope and you will see many tiny balloonlike bodies. See the picture marked with a square. 🟦 They have no green color, even though they are plants. Each of the "balloons" is a yeast **cell.** Each yeast cell is a living thing.

To live, the yeast cell uses food substances, especially sugar. The yeast cell can live on sugar and grow on it. As the cell grows, something astonishing happens. (It *is* astonishing when you stop to think of it.) As the cell grows, it produces another yeast cell. That is, the yeast cell **reproduces** itself.

It is not hard to make a model of a yeast cell reproducing. Take a piece of modeling clay and make a ball. Then from another piece of clay make a smaller ball, and stick it to the larger one. You have a model of a yeast cell with a new cell coming from it.

How long does it take a yeast cell to do this astonishing trick? It takes only a few hours when the cell has enough sugar and oxygen and the right temperature.

To live and grow takes energy, of course. Where does a yeast cell get energy, then? The yeast cell gets energy for growth from sugar. See for yourself what yeast plants do to sugar. Do the investigation on the next page.

AN INVESTIGATION into the Action of Yeast on Sugar

Needed: a packet of powdered yeast, some sugar, half a glass of warm water, half a glass of limewater, a glass flask, a rubber or plastic delivery tube, and modeling clay

Dissolve 2 level teaspoonfuls of sugar in the warm water. Take about half the powdered yeast out of the packet, and put it in the water also. Pour this mixture into the flask. Insert the delivery tube and quickly seal the flask with clay. Place the end of the delivery tube in the limewater. ■ Observe what happens.

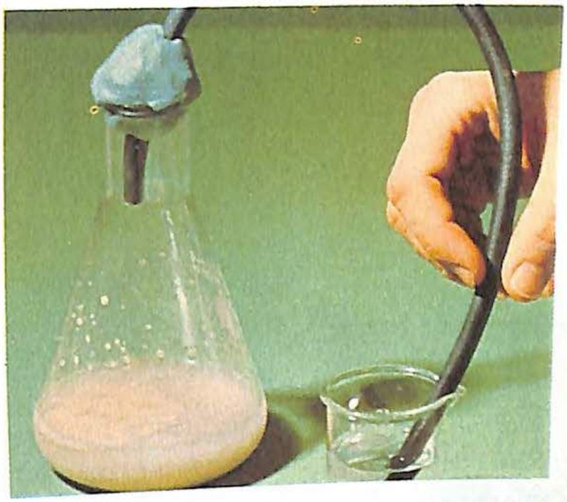
Here is what happened in one trial. In about 10 minutes bubbles came from the delivery tube into the limewater. ● What happened to the limewater? ▲

What does it mean when limewater turns milky?

When limewater turns milky, carbon dioxide has entered it. The bubbles coming from the delivery tube were carbon dioxide gas. The yeast in the sugar solution made carbon dioxide gas.

Watch what happens inside the flask when yeast and sugar and warm water are mixed. Do you see any changes taking place?

Additional Investigation: Put the other half of the yeast in half a glass of warm water with *no* sugar in it. Predict what will happen, and check your prediction. How do you explain the result?



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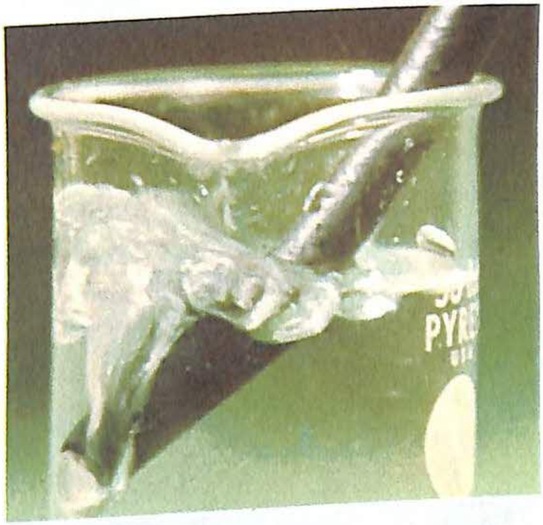

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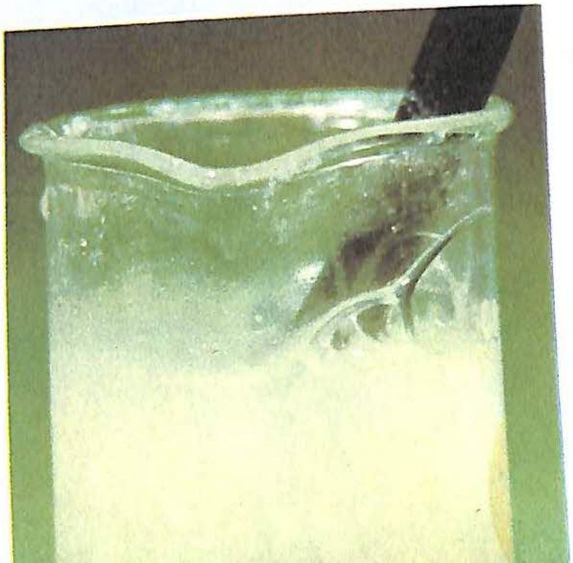

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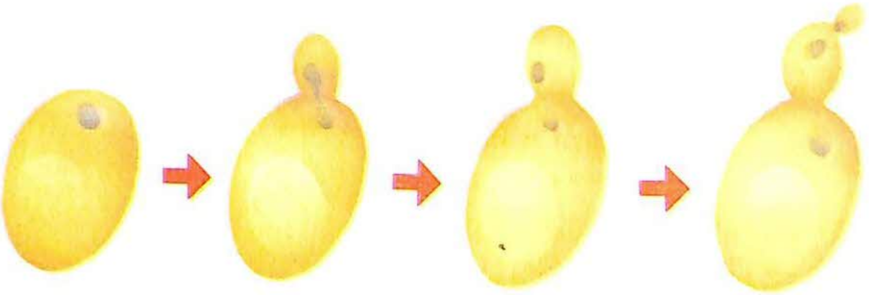


Breaking Down Molecules

How does a yeast cell reproduce? As a yeast cell grows, it forms a **bud.** The bud grows and becomes a new yeast cell. Then that cell buds, and so on. Yeast cells reproduce by budding.

When yeast cells are put into a sugar solution, they make carbon dioxide gas.

Now, we already know something about carbon dioxide. We know that it is a combination of carbon and oxygen. To make carbon dioxide, the yeast cells must get atoms of carbon and atoms of oxygen from somewhere.

Where do the yeast cells get carbon atoms? Sugar is made up of atoms of carbon and hydrogen and oxygen. The yeast cells take carbon atoms from the sugar molecules.

The yeast cells combine these carbon atoms and oxygen atoms from the air to form carbon dioxide. We can write an equation about this. In the yeast cell,

sugar + **oxygen** ⟶ **carbon dioxide** + **water**

The yeast cell, a tiny living thing, can break down sugar molecules!

BEFORE YOU GO ON Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A yeast plant is a living thing made up of
   a. one cell b. many cells
2. When a yeast cell buds it
   a. reproduces itself b. only grows

3. The yeast plant gets its energy from
   a. the food it uses b. reproduction

4. When a yeast cell uses sugar, the cell gives off
   a. oxygen gas b. carbon dioxide gas

USING WHAT YOU KNOW

1. Complete this word equation about what happens in the yeast cell.

sugar + ? ⟶ carbon dioxide + water

2. Yeast can be used, like baking powder, to make bread "rise." What does yeast do that raises bread?

ON YOUR OWN

Find out why yeast is classified as a plant. Why isn't yeast called an animal?

2. The Cell's Energy Process

Gasoline supplies the energy that makes a car go. Oil is burned in a diesel locomotive so that it can do work. Kerosene supplies energy for jet engines. If work is to come out of a machine, energy must be put in, as you know. Just the same thing is true of a yeast cell. Energy must be put into a cell, if the cell is to do its work.

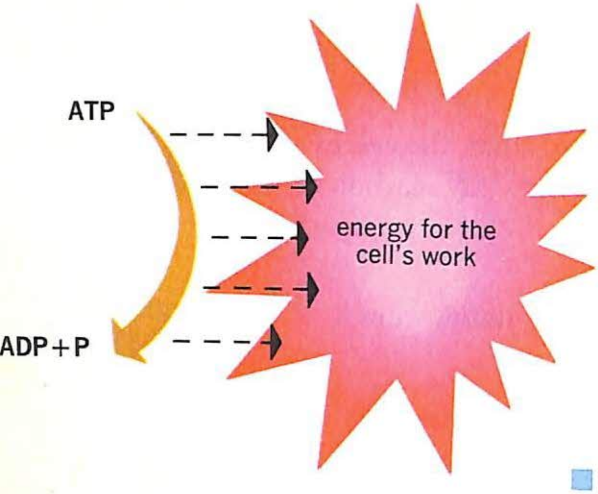
In the yeast cell, food substances are the fuel. Food substances supply energy for the cell's work. How does the cell change food into energy? Does the cell burn the food, as a jet engine burns its fuel, to get energy?

Changing Food into Energy

What is "burning," anyway? What is happening when a thing burns?

When a candle burns, its paraffin fuel combines with oxygen taken from the air. This combining with oxygen is called **oxidation**, as you may remember having learned in Unit Two. When you see something burning, you see oxidation taking place. That flame you see means that some substance is combining with oxygen.

In oxidation, compounds called oxides are formed. One oxide you know is carbon dioxide. The burning candle forms carbon dioxide gas by combining carbon and oxygen.



Oxidation can happen *without* a flame, though. When iron rusts, for instance, it is combining with oxygen taken from the air. This is oxidation, again. Iron oxide is formed. Rusting, then, is a kind of burning without flame. Oxidation can happen with a flame, or without a flame.

In your body, right now, food substances are combining with oxygen. Oxidation is happening in your body. Food substances are oxidized in your body. Notice we now use the word "oxidized," rather than "burned" because there is no flame.

In your body the carbon in a food substance combines with oxygen in your body. Oxidation takes place. *And energy is released.*

We can write an equation about this:

carbon + oxygen ⟶
carbon dioxide + **energy**

Food substances contain hydrogen, too. When hydrogen in a food substance combines with oxygen, oxidation is happening. *And energy is released.*

hydrogen + oxygen ⟶
water + **energy**

This is how you get energy. In your body cells, now, oxidation is going on. Oxidation of food substances supplies your cells with energy. Most of the food substances oxidized in your body have carbon and hydrogen in them. Sugar, starch, meat, cheese, milk, all have carbon and hydrogen in them. You get energy from them by oxidizing them.

There is a hitch, though. This energy must be changed into another form before a cell can use it. However, your cells manage to do this too.

The Cell's Energy Machine

When you turn on an electric fan, you are really turning on a machine for changing energy. The fan changes energy from one form to another. After all, the electrical energy in the wall outlet isn't of much use to you just as it is. So you turn on a machine that can change that energy into a useful form. The electric fan changes the energy of electricity into the energy of moving air.

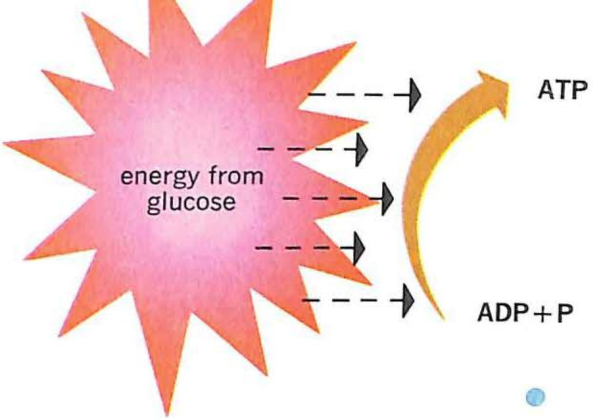
A cell has a kind of machine for changing the energy it gets into the sort of energy it can use. There is a huge molecule that does the job.

This molecule is called an **ATP** molecule. ATP stands for adenosine triphosphate (ad′ə·nō′sin trī·fos′fāt). But scientists say ATP; so, why don't you?

Let's imagine how a cell's energy machine works. To begin with, the cell has inside it a good supply of ATP molecules. Now the cell begins to break down these ATP molecules. *As the ATP breaks down, energy is given up.* This is the sort of energy that the cell can use for its work.

As ATP is broken down by the cell to yield energy, the ATP breaks into smaller pieces. Scientists call these smaller pieces **ADP + P,** for short. Here is one way of showing this.■

If all the ATP the cell had was broken down into ADP + P, the cell would have no ATP and no more energy for its work. However, the cell gets more ATP. The cell's energy machine goes into reverse! It changes the ADP + P back to ATP.●



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Notice that this is where the kind of sugar called **glucose** comes in. The cell now needs energy to build up ATP. The cell gets energy for building up ATP by oxidizing glucose that it takes in.

There is a kind of merry-go-round here, isn't there? The ATP breaks down into pieces. As it does so, it yields energy for the cell's work. Then the ATP builds up again from its pieces. The energy for building up the ATP is taken from glucose. Now the ATP is ready to break down again.▲ This merry-go-round is

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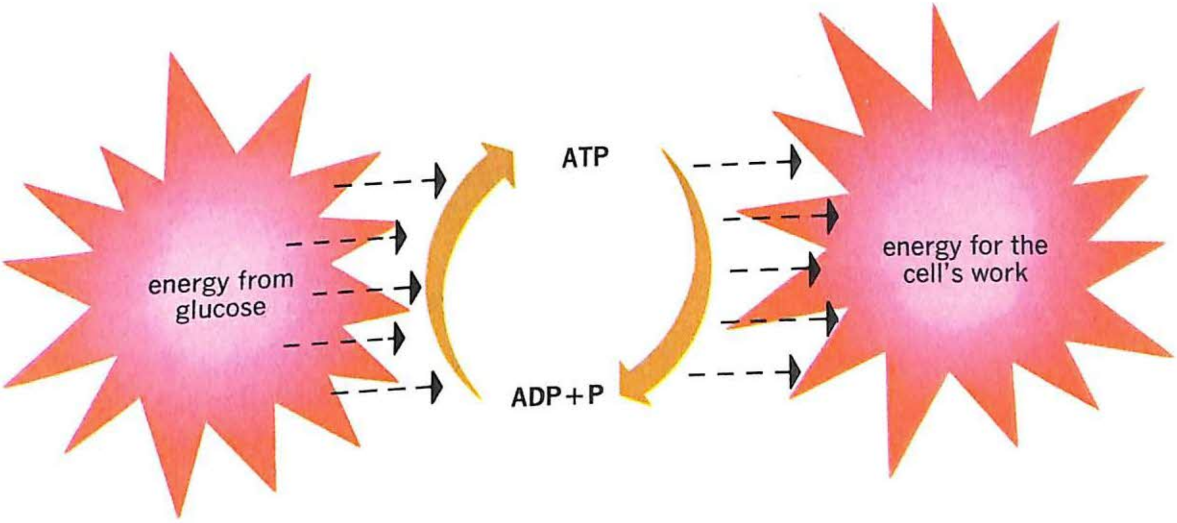


called an **energy cycle.** You can see that this energy cycle can keep going around and around, as long as the cell takes in glucose and has work to do.

Of course these pictures show an imaginary model. A cell does not look like this. However, the cell does behave as if it had an energy machine inside it. It does make use of ATP to get energy.

We know what ATP looks like. It is a powdery, yellowish substance. We know what glucose looks like. It is a powdery, white substance. But scientists don't know yet just how energy comes out of breaking down ATP.

We do know that it is the cell that does the job. The cell is the smallest working part of a living thing. The work of a living thing is done by its cells.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The main substance oxidized in the cell is
   a. glucose   b. starch

2. For the cell to have energy for its work, it must first build up
   a. glucose   b. ATP

3. Energy is given off during the breaking down of
   a. ATP   b. ADP

B. Write a paragraph or two on this topic: "ATP—Why My Life Depends on It."

USING WHAT YOU KNOW

1. When ATP breaks down,

$$\text{ATP} \longrightarrow ? + \text{P}$$

2. When ATP is built up,

$$\text{ADP} + ? \longrightarrow \text{ATP}$$

3. A cell must have energy to build up ATP. What main food substance supplies this energy?

3. Getting Inside a Cell

Bend your finger.

That seems a silly thing to ask. However, bend your finger, and think for a moment of what you know now is happening. To move that finger, ATP is breaking down and yielding energy. To build up the ATP so that it can be used again, food substances are being broken down. They yield energy to build up the ATP. This breaking down of ATP and building it up again is the cell energy cycle. (You may unbend your finger now.)

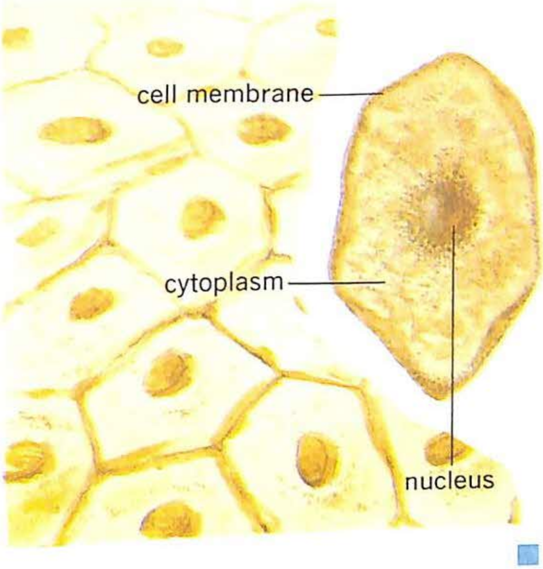
The cell energy cycle goes on in *all* cells. In every cell in your body, ATP is being broken down and rebuilt right now. Let's look at your cells.

Inside Cells

These flat, odd-shaped bodies are cheek cells.■ They are very small. It would take thousands of cheek cells to stretch across the circle at the end of this sentence. ⊙

Have you observed that each of these cells has a dark spot in the middle? This spot is the **nucleus.** Around the nucleus is more material. It is called **cytoplasm** (sī′tə·plaz′əm). Around the cytoplasm is a very thin skin. This skin is the **cell membrane.**

A cheek cell looks very different from a yeast cell. But like a cheek cell, a yeast cell has a nucleus, cytoplasm, and a cell membrane.



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Nucleus, cytoplasm, and cell membrane are important parts of these cells. To see these important parts clearly, make a model. You will need a potato and a marble.

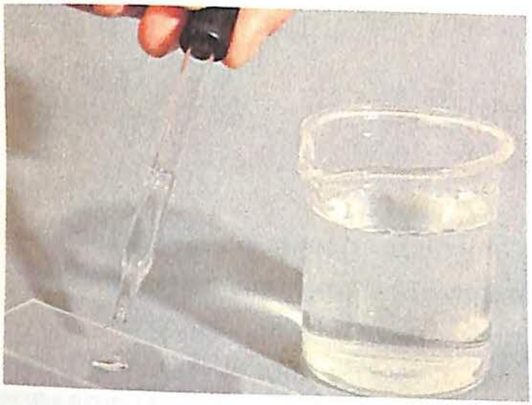
Cut the potato in half. With a spoon, hollow out a small space in each half. Put the marble in this space. The marble is a model of the nucleus of a cell. The white part of the potato stands for the cytoplasm. The skin stands for the cell membrane.

Of course this cell model doesn't work. It is only a model of what some cells look like, to make the idea a bit clearer.

However, you can easily observe some cheek cells of your own, if you have the use of a microscope (about 200×). To see cells for yourself, you can try the investigation on the next page.

AN INVESTIGATION into Your Cheek Cells

Needed: a 200× microscope, a glass microscope slide, a small bottle of iodine, a bottle of water, a clean medicine dropper, and a clean toothpick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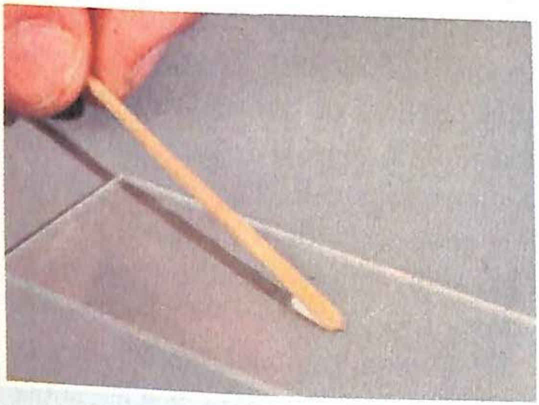
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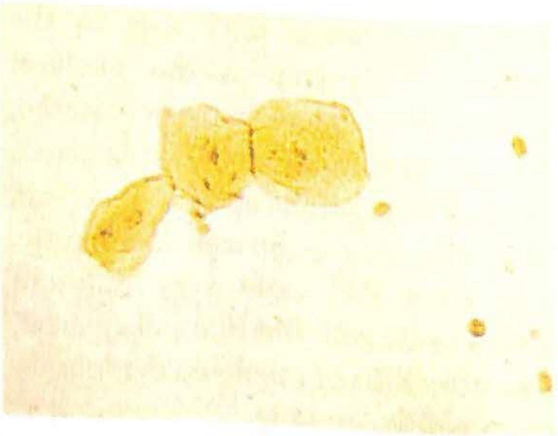
Put a drop of water on the center of the glass slide. ■ Gently scrape the inside of your cheek with the side of the clean toothpick. A whitish material will collect on the toothpick. The material is made up of cells from your cheek.

Mix this material in the drop of water. ● To see the cells more clearly under the microscope, stain them. Add just one drop of iodine solution to the drop of water on the slide. ▲ (To make the solution, add 1 dropperful of drugstore iodine to 1 cupful of water.)

Place the slide under the 200× lens of the microscope. The shapes are cells from the skin of your cheek. ◆ Can you observe a dark spot in each cell? It is the nucleus of that cell, stained by the iodine solution.

Additional Investigation: Let the drop of water on the slide dry, and observe what happens to the cells. What do you think this result means?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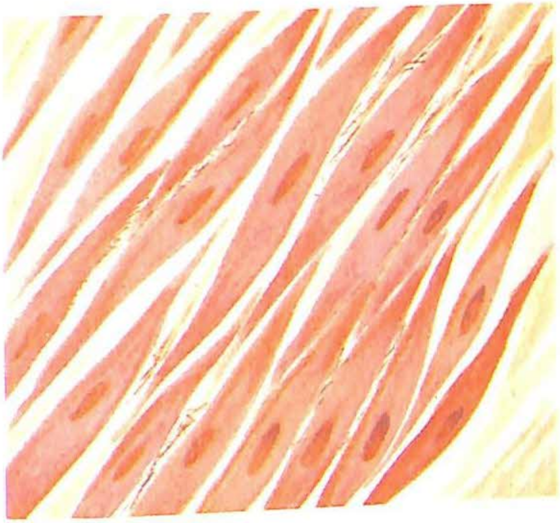
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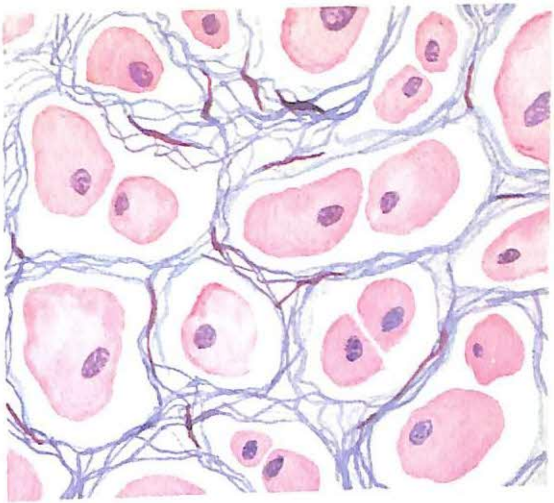
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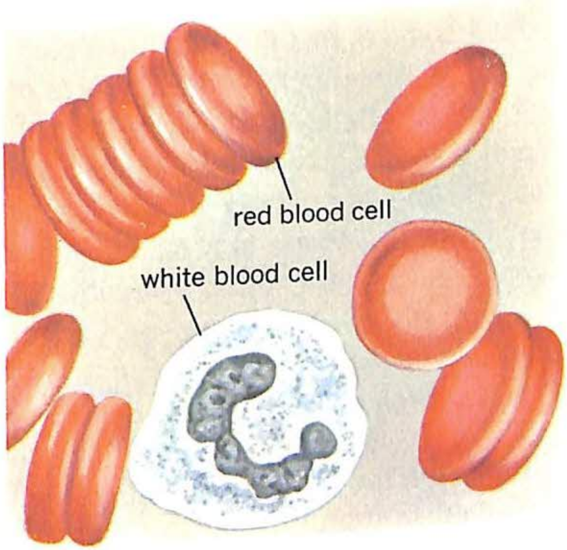

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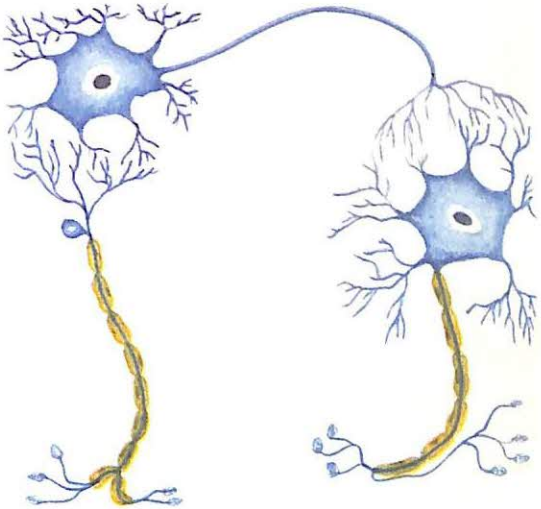
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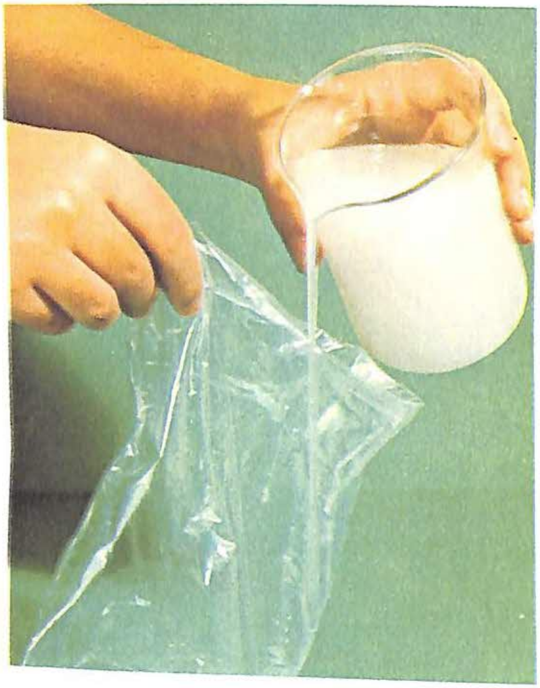
Your Tiny Energy Machines

There are millions upon millions of cheek cells in your cheeks. Feel a muscle in your arm. There are millions upon millions of muscle cells in your muscles. One kind of muscle cell looks like this.■ Touch your ear. There are millions of cells there. Some of them look like this.● If you could look into your blood, you would find more millions of cells.▲ In your brain are still more millions of cells.◆ *You are made of many kinds of cells.*

These cells certainly look different. They *are* different, for they have different jobs to do. Yet each one of them has a nucleus, cytoplasm, and a cell membrane.

These cells are alike in other ways, too. Food substances go into every

MAKING A MODEL: The Cell Membrane



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Needed: a box of clear gelatin, some starch, cologne, three or four small plastic bags (sandwich size), string, three small pieces of clay, scissors

Boil 1 cup of water and stir in a packet of gelatin. This will dissolve the gelatin. Then add $\frac{1}{2}$ cup of cold water. Add a teaspoonful of starch, and another teaspoonful of cologne. Stir to mix with the gelatin.

Pour some of this mixture into a plastic bag.■ An amount about the size of a Ping-Pong ball will do. Add a small round piece of clay about the size of a pea. Tie the bag tightly with string so that it has the shape of a ball.● There should be as little air as possible in the bag. Cut away the unused part of the bag with scissors.

Make three or four of these cell models, so that you can try several investigations. Let the gelatin cool and harden overnight in the plastic bags.

The gelatin is a model of the cytoplasm in a cell. The plastic bag stands for the cell membrane. The clay stands for the cell nucleus. Use this cell model for the next investigation on page 158. It will show you something that a cell membrane can do.

cell. Oxygen goes into every cell. In every cell the food substances are broken down and yield energy. This energy is used to build up ATP. In every cell ATP breaks down and yields energy for that cell's work.

So each cell has a tiny energy machine. You use the energy in your cells every moment, for play, and work, and growth. You are using the energy of your cells right now, to read these words.

Getting into a Cell

Now, here is a puzzle. We know that substances go into a cell and provide it with energy. Oxygen goes in, for example. Sugar goes in. So do other food substances. Substances come out of a cell, too.

How do substances get in and out of a cell?

The pictures of cells that you have seen here show no openings in the cells. The cell membrane around the cell shows no door. There is none, in fact. Each cell is sealed inside its cell membrane much like a potato sealed in its skin.

How do substances get in and out? To see for yourself, make the model cell shown on the opposite page, with a plastic bag and starch and gelatin. Then put the model cell to work in the investigation on the next page. It will show you an important thing that a cell membrane does.

The Important Membrane

Everyone knows what happens to a lump of sugar at the bottom of a glass of water. The sugar dissolves in the water. But not everyone realizes what happens next. As the sugar dissolves, it *spreads* through the water. No stirring is needed! If it is given time enough, the sugar will spread through every bit of the water.

When a substance spreads in this way, we say that the substance **diffuses.** Sugar diffuses through water. Oxygen diffuses through water. Carbon dioxide diffuses through water. In fact, if a substance dissolves in a liquid, it can diffuse through the liquid.

Iodine diffused through the water in the investigation into the model cell. However, the starch *inside* the model cell membrane turned blue. *This evidence shows that iodine diffused through the membrane.* The iodine diffused through the plastic membrane almost as if the membrane weren't there!

Scientists have discovered, after much investigation, that only substances that dissolve can pass through membranes. Oxygen dissolves in water, and oxygen diffuses easily through a cell membrane. Carbon dioxide dissolves in water and diffuses easily through a cell membrane. So does sugar. Most compounds and elements that dissolve in water can

AN INVESTIGATION into What a Membrane Does

Needed: a gelatin cell model, iodine solution, a bowl or jar, water

Fill the jar about three-quarters full with warm water. Add just enough iodine solution to turn the water a light tan.■ Place the gelatin cell model in the jar.●

These are the photographs of one trial. What has happened to the cell model?▲

How can this be explained?

Reason with us this way. You know that iodine turns starch blue, and then black. The starch inside the membrane slowly turned blue. So iodine must have reached the starch inside the membrane. *Iodine must have gone through the membrane.* Yet the membrane seems solid enough!

Did starch pass the other way through the membrane, to the water outside?

If starch had passed through the membrane, it would have met the iodine in the water outside the membrane. The water outside the membrane would have turned blue. Since the water did not turn blue, starch did *not* pass through the membrane. Iodine did.

Additional Investigation: Place another cell model in a dish of clear water. After a few hours, smell the water in the dish. What has happened to the cologne in the plastic bag?

Now go back to "The Important Membrane" on page 157.

■

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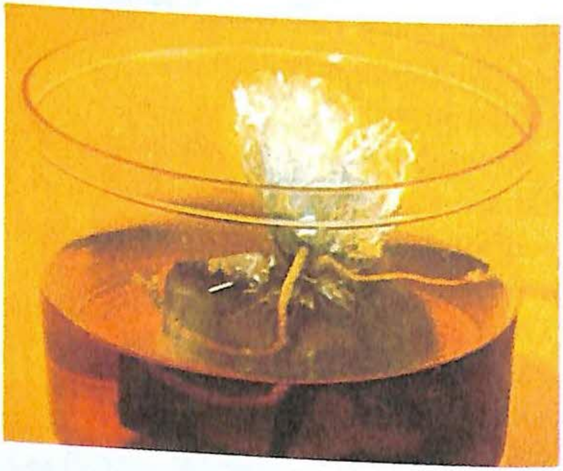
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go through cell membranes by diffusion.

Starch does *not* dissolve in water. As the investigation showed, starch does *not* diffuse through the plastic membrane of the model cell.

The plastic cellophane is only a model of a cell membrane. It acts like a real cell membrane in one way only. Some substances diffuse through it and some do not. However, it does show us an answer to our puzzle. This is how substances can enter and leave a cell that has no opening—they pass through the cell membrane by diffusion.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A substance placed near a cell was not able to get into the cell. It was kept out of the cell by the

a. cytoplasm b. cell membrane

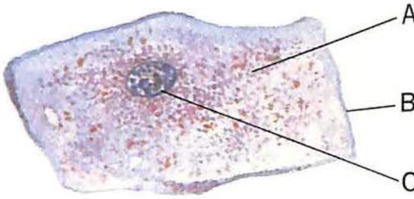
2. Substances get into and out of a cell by the process of

a. oxidation b. diffusion

B. Write a paragraph or two on this topic: "The Importance of the Cell Membrane."

USING WHAT YOU KNOW

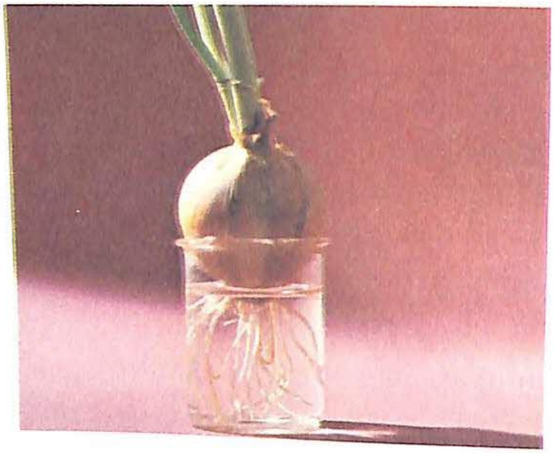
1. Name the parts of this cell.



2. A test tube is filled with water and glucose. A membrane is fastened over the mouth of the tube. Then the mouth of the tube is placed in a jar of water. What might you expect to find in the water in the jar after a while? Why?

ON YOUR OWN

Try this investigation. Make a gelatin cell model, but this time add a teaspoonful of ammonia instead of starch. Does ammonia diffuse through the plastic membrane? Remember that pink litmus turns blue in the presence of ammonia.



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4. Cells in a Plant

Place an onion on top of a jar filled with water up to the bottom of the onion. ■ Keep the jar in a cool place, out of the sunlight. In a few days green shoots will sprout from the onion bulb, and you can examine the green plant cells under a microscope.

What Makes It Green?

Under a high-power lens you can't miss seeing, inside the cells, tiny green bodies shaped like basketballs. ● They give the plant its green color. They are called **chloroplasts** (klôr′-ə·plasts). *Chloro* means *green. Plast* means *body.*

Now look at some cells from the bulb of the onion. ▲ As you might expect, there are no chloroplasts. The bulb is not green.

Chloroplasts are found in many different plant cells. ◆

Look closely at these pictures of different plant cells. Notice that a cell has a nucleus, cytoplasm, a cell membrane, and chloroplasts. Chloroplasts have different shapes.

Do you observe something new about these cells? It may help if you compare them with the body cells on page 155. Do you observe that these plant cells have *thick sides?* You may have thought that this was simply a thick cell membrane—but it is not. It is something that the cells on page 155 do not have at all. It is a **cell wall.** The cell membrane is still there, inside the cell wall. *Plant cells have cell walls.* Animal cells do not have cell walls.

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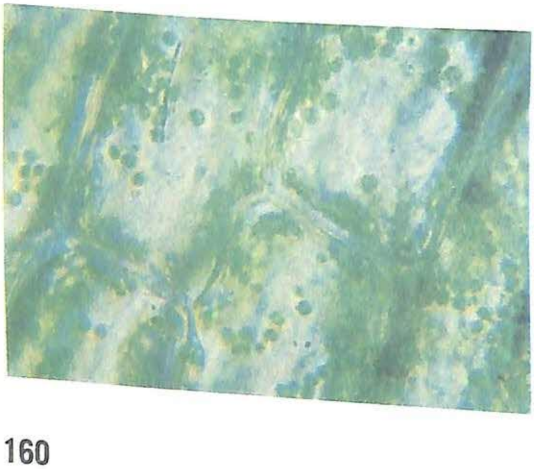

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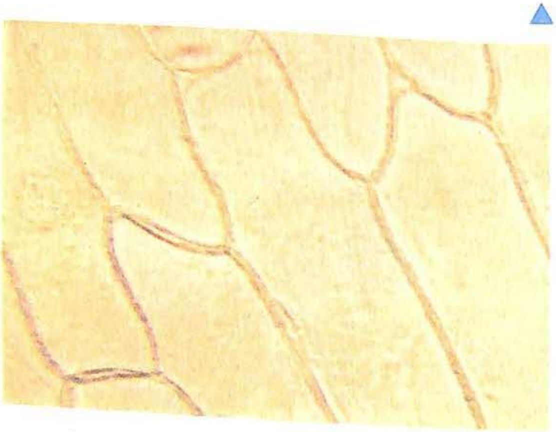
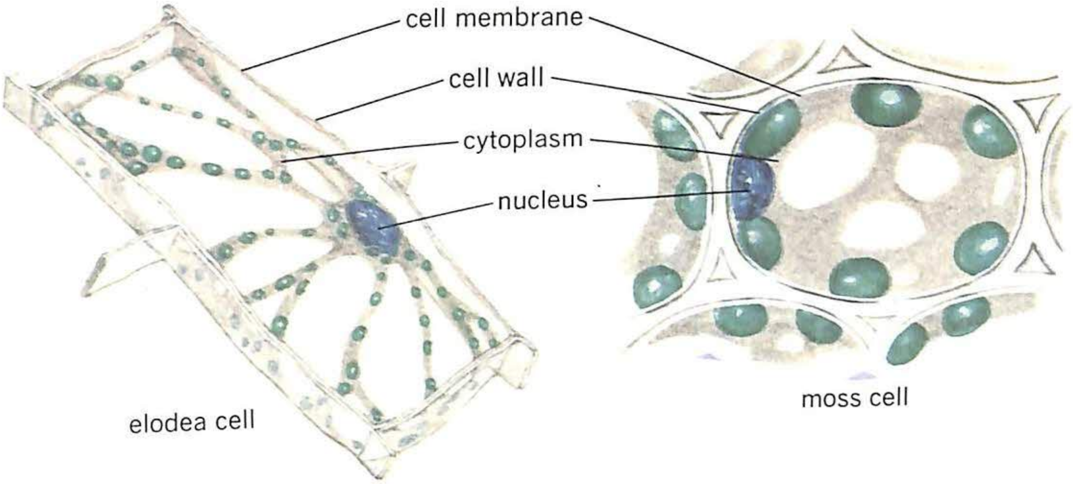




The cell walls of a plant are made of **cellulose** (sel′yə·lōs). Wood, for instance, is mainly cellulose. When wood is burned, it is mainly the cellulose in millions of plant cells that is burning. The fluffy boll of a cotton plant is mainly cellulose, and so is a cotton dress or shirt. The paper on which these words are printed is made from dead cell walls, the cellulose of plants.

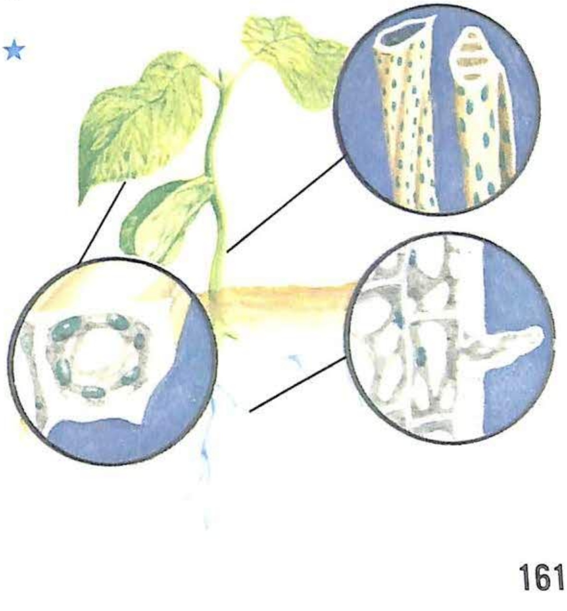
Cells That Work Underground

Here is a picture of a young bean plant, about two weeks old.★ The leaves are green. The roots are whitish. Where would you expect to find chloroplasts? In the green leaves, of course, and not in the roots.

Look at the roots, though. Observe the tiny hairs.★ They are called ***root hairs.*** These hairs are cells. Root hairs and roots anchor the plant to the soil. This is not all that the cells in the roots do, however. Each root hair takes in water and minerals from the soil. The plant uses the water and the minerals. These root hair cells do their work underground.

Look at the different parts of the bean plant as they are seen under the microscope. The bean plant is a living thing. It is made of cells, as you would expect. There is something more. *There are different kinds of cells in different parts of the plant.*

It seems that the **structure** of a plant cell, the way it is built, has



AN INVESTIGATION into the Skeleton of a Leaf

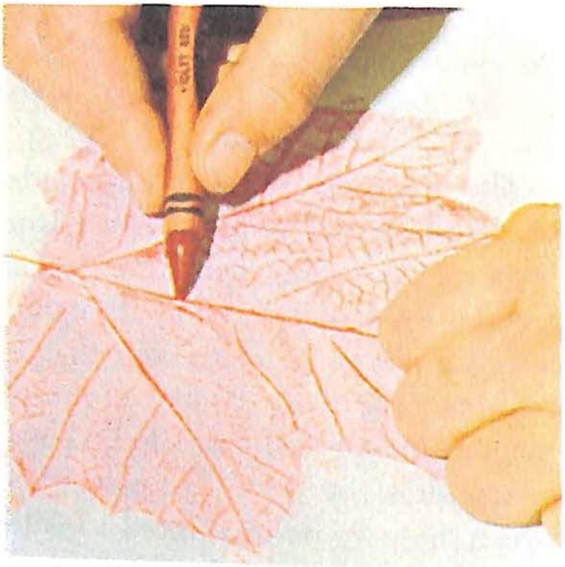
Needed: a large leaf from a tree, a sheet of white paper, and a crayon

Place the leaf face down under the sheet of paper. Hold the paper and the leaf down firmly so that they can't move. ■

Rub the broad edge of the crayon over the surface of the paper, above the leaf. Use long, quick strokes. ● As the crayon crosses the raised parts of the leaf, it will outline them on the paper. This is called "making a rubbing." A kind of skeleton of the leaf will be outlined on the paper. ▲

What is a leaf's skeleton made of? It is made mainly of cellulose. The cellulose skeleton of a leaf gives it strength and stiffness.

Additional Investigation: Place a thin piece of cellulose under a microscope that magnifies about 200X. Can cell shapes be seen?



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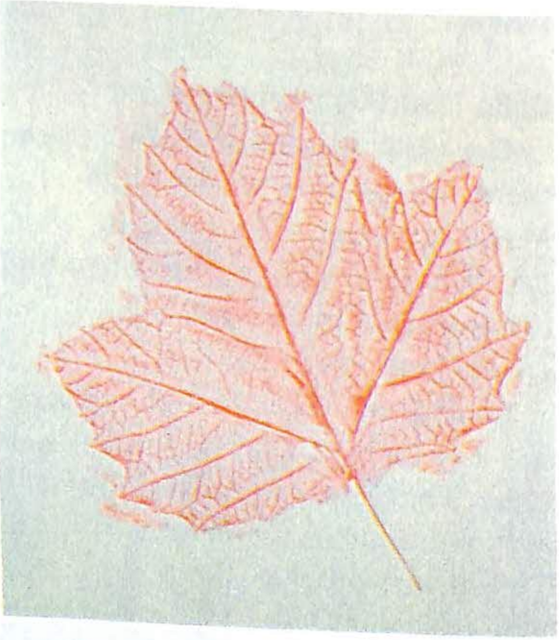

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something to do with its work. Root cells have a different structure and different work from cells in a leaf.

The few plants and animals we have studied so far have been made up of cells. It's reasonable to expect that other plants and other animals are made up of cells too. Let us go further and see if this is so.

Without cellulose a plant would be rather limp and flabby! See for yourself how cellulose forms a kind of skeleton for a leaf. Try the investigation on the opposite page.

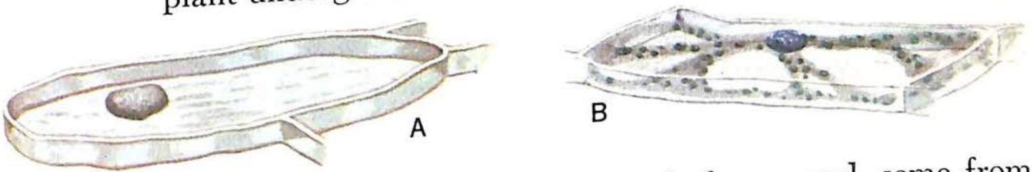
BEFORE YOU GO ON

A. To help you fix in mind the concepts of this section, draw two cells, a green plant cell and an animal cell. How are these cells different? How are they alike?

B. Write a paragraph or two on this topic: "Differences Between Green Plant Cells and Animal Cells."

USING WHAT YOU KNOW

1. Here is a picture of two cells from a single plant. Which cell would you expect to find aboveground, perhaps in a leaf? Which one would you expect to find in part of a plant underground?

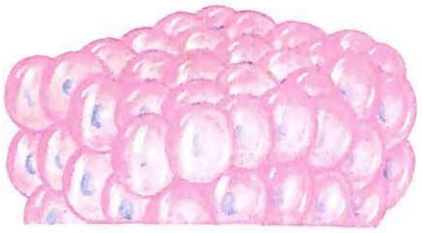


2. Some kinds of paper are made from wood, some from cotton rags. Whether it is made of wood or cotton, paper is mainly cellulose. What part of a plant is used to make paper?

ON YOUR OWN

If you can get a microscope, observe the difference between cotton threads and wool threads. Would you expect a difference because one is from an animal and the other from a plant?

5. A Whole Skin



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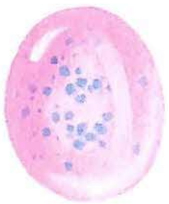

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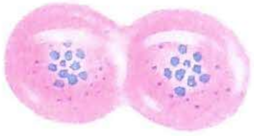

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By now you must have had many cuts. Yet your skin is whole. Skin heals.

What happens when skin heals? Scientists have found out that healing is mainly the work of cells. For healing to take place, more skin has to be made. Since skin is made up of cells, more skin cells must be produced. Cells can produce more cells, as you know. Cells can reproduce, in other words. Yeast cells reproduce by budding. But skin cells reproduce in a different way.

How Skin Cells Reproduce

Under the top layer of your skin are cells shaped like grapes. These skin cells fit together like this. ■

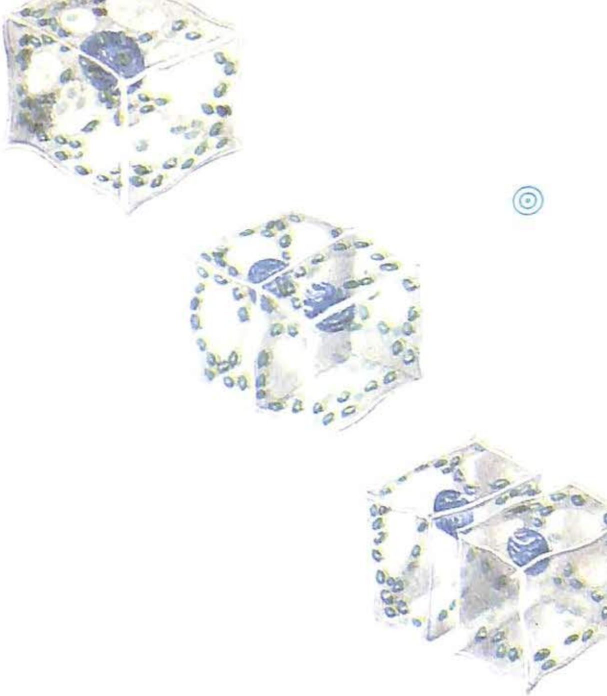
Each of these skin cells has a nucleus, cytoplasm, and a cell membrane—as all cells do. ● These cells reproduce to form more skin cells.

When the time comes for one of these cells to reproduce, the nucleus starts to divide in two. ▲ Then the cell pinches in the middle. ◆

Finally there are two skin cells made from one cell under the skin. Each new cell has its own nucleus. ★ The cell has reproduced itself by **cell division.**

Each new cell can reproduce by cell division too. The cells under the skin on each side of a cut make new cells by cell division. The new cells close up the cut. They also produce new skin cells. We say the skin heals.◆

This is why you have a whole skin in spite of all the cuts you have had.



A Cut in a Tree

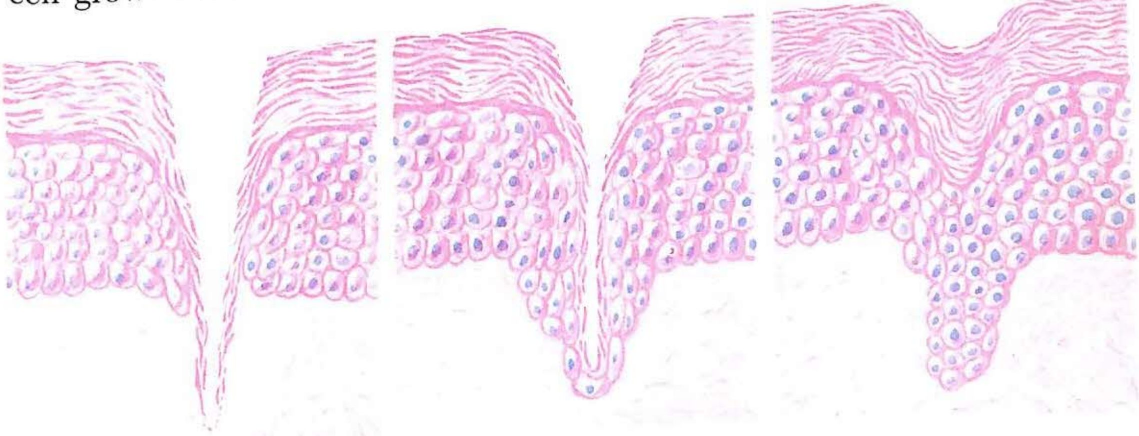
Have you ever noticed how a tree heals a cut in its bark?

Beneath the bark of a tree are layers of cells called the **cambium** (kam′bē·əm). The cambium is made of cells that divide easily. One of these layers reproduces to heal a cut in the bark. After a year or two, or longer, the cut is covered with new bark.

Like skin cells, cambium cells reproduce by cell division. However, if you could watch cambium cells dividing, you would see that they do not divide as skin cells do. For the cambium cell is a plant cell, not an animal cell. A new cell wall grows inside the plant cell.◎ This new wall divides the cell in two. The nucleus of the cell splits to form two nuclei. Each new cell grows until it is the same size as the old cell was. And each new cell can reproduce by cell division.

Most plant cells divide by building a new cell wall. Most animal cells divide by pinching in. One way or the other, cell division goes on as long as the plant or animal lives.

How fast can cells reproduce themselves? See for yourself, by doing the investigation on the next page. ◆



AN INVESTIGATION into the Reproduction of Yeast Cells

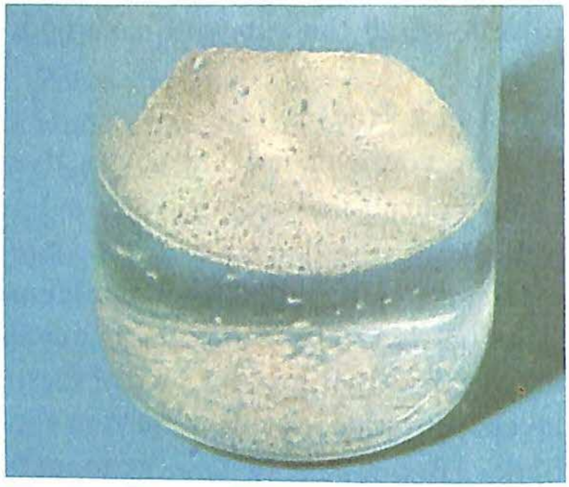
Needed: a packet of dry yeast powder, two lumps of sugar, two jars with screwtop lids, handkerchief, water

Begin by making a guess as to how fast yeast cells reproduce. See if your guess is confirmed by this investigation.

Put water into one jar until it is about one-quarter full. Dissolve two lumps of sugar in the water. Lightly cover a dime with yeast powder. Put this amount of yeast into the jar of sugar water. Screw a cap *loosely* on the jar, so that dust can't get in but gas can get out. There will be about 2 million yeast cells in the jar. ■

Leave the jar at room temperature for 4 days. Here is what happened in one trial. ●

More yeast cells form by cell division. How much more yeast is there now? Strain the yeast mixture through a closely woven handkerchief, or through filter paper, into the second jar. This will filter out the yeast cells. Let them dry overnight. ▲ Compare them with the amount of yeast you started with.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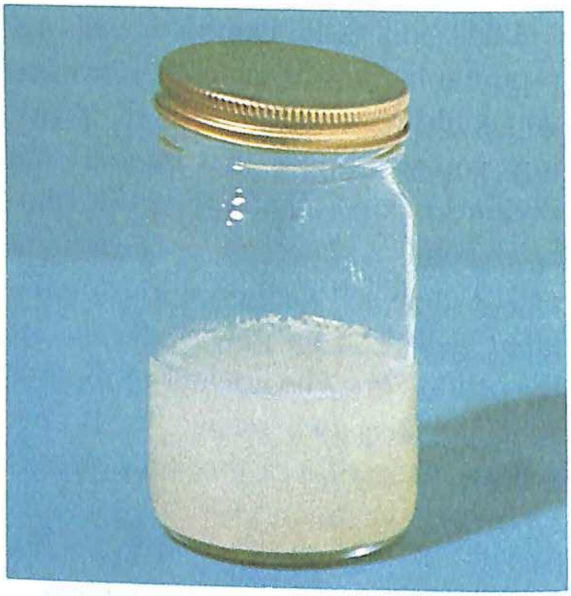
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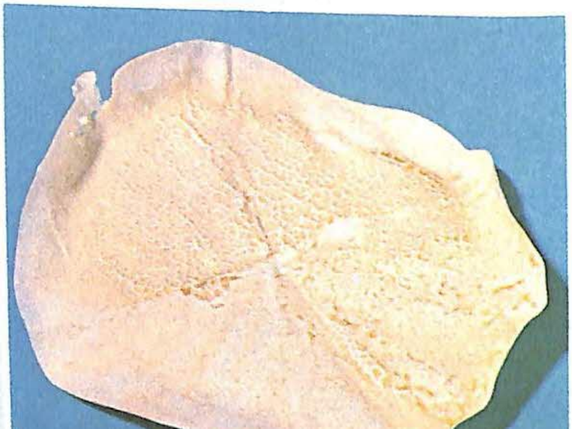
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Dividing Cells

Cell division is going on in every living thing. Cells divide very fast in living things that have just been formed. In a frog's egg that is growing into a tadpole, the cells are dividing quickly. The cells of the robin growing inside the egg are dividing quickly. The cells of the rabbit inside its mother are dividing quickly.

All around you, as you read this, cells are reproducing in living things. Cells are reproducing in you.

There are differences, however. For instance, cells reproduce in a radish, and in yeast. A radish, however, has many different kinds of cells. Yeast has only one kind of cell. A radish is a **many-celled** living thing. A yeast is a **single-celled** living thing. Somehow, reproduction in a many-celled living thing makes different kinds of cells. Somehow, reproduction in a single-celled living thing makes just one kind of cell. It is an astonishing difference.

In the next section we will take a close look at some one-celled animals, and see how they reproduce. Later we will look at some many-celled living things and see what the difference is.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the main concepts of this section.

1. A cell reproduces by means of
a. diffusion b. cell division

2. The result of cell division is two cells that are
a. very much alike b. very different

3. The cells in a plant which divide when the plant repairs itself are
a. leaf cells b. cambium cells

4. A cell that doesn't pinch in when it divides is
a. an animal cell b. a plant cell

B. Write a paragraph or two on this topic: "How Cells Divide."

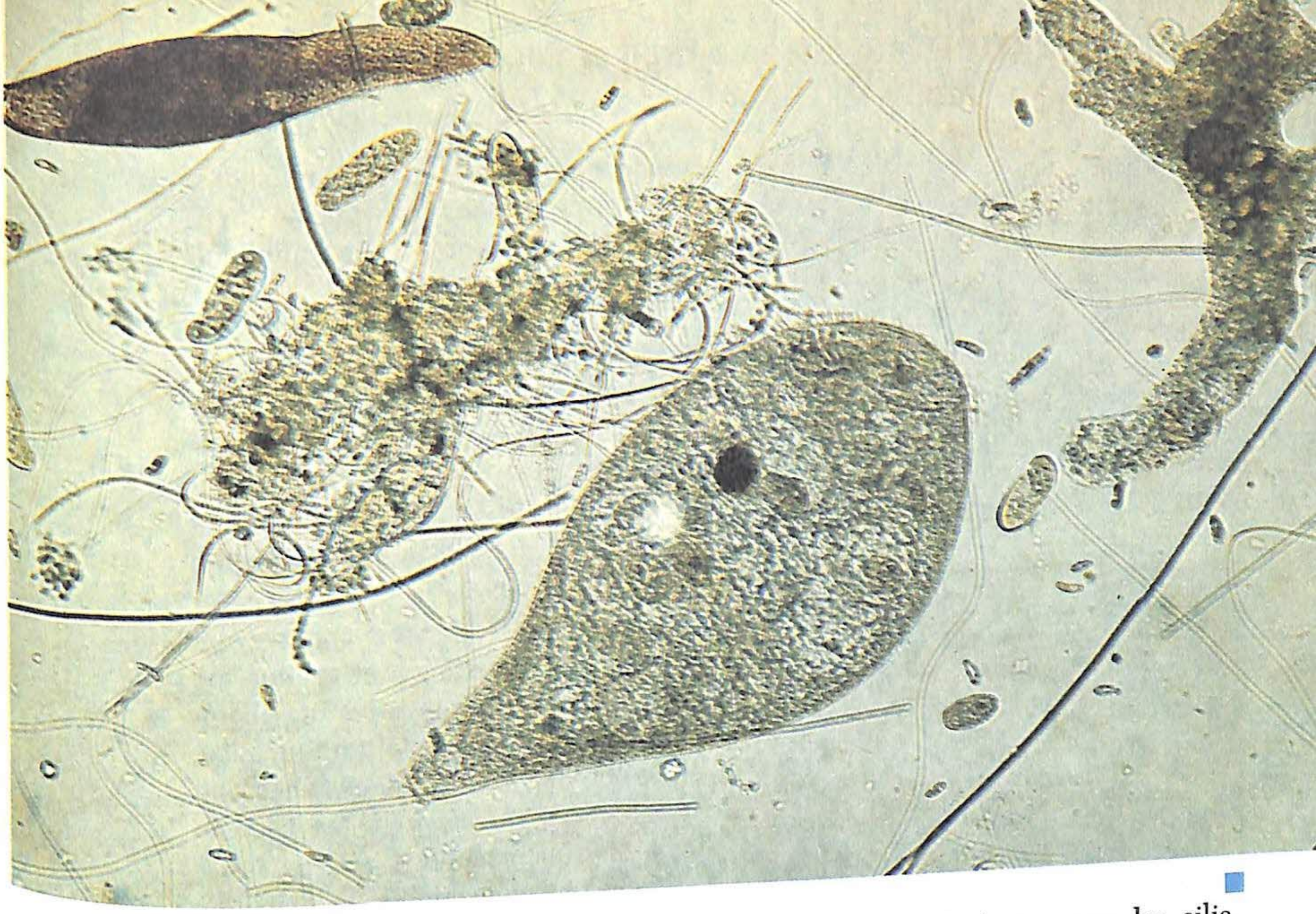
6. Just One Cell

If you go for a walk in the woods, take along a small, covered, plastic jar. When you come upon a stream or a pond, scoop up some of the water. Get some water plants and mud, too.

Bring the jar to class, and place it where it will be at room temperature and out of the sun. Add to the water a bit of hard-boiled egg yolk the size of a pea. Or add ten grains of rice. **Bacteria,** tiny one-celled plants, will use these substances to grow and to reproduce. As the bacteria feed on them, the egg yolk or the rice will decay.

The bacteria will reproduce rapidly. They will divide about once every 20 minutes. They are food for some one-celled animals that live in pond water. These one-celled animals are the ones we want to study.

At first the pond water in your jar may be fairly clear. A few days after the food is added, the water will become cloudy with bacteria. Soon after that, the water will swarm with tiny animals just large enough to be seen with your eye.



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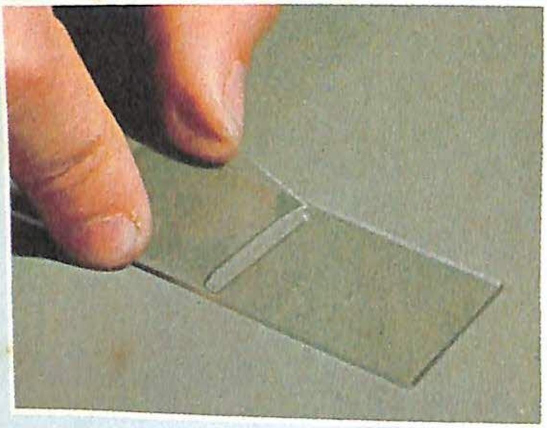
In a Drop of Water

Look at the amazing world in a drop of pond water. ■ In a drop no larger than a dime, dozens of different animals are scurrying about, feeding and reproducing. The *paramecium* (par′ə·mē′she·əm), shaped like a slipper, twists and turns and darts from place to place at tremendous speed. It moves by waving the hairlike structures on its body, which are called **cilia** (sil′ē·ə). The cilia push against the water like oars. They also steer bits of food into the paramecium's mouth. *Vorticella* (vôr′ti·sel′ə) is another animal that moves by cilia. The vorticella's long stalk suddenly coils like a spring, pulling back out of harm's way. Then it slowly stretches out again and the animal goes on feeding. Its cilia make a kind of whirlpool that draws food into its mouth.

The *stentor* (sten′tôr) sways from side to side, and can shrink down to hide where it is standing. The stentor's cilia fan water and food into its horn.

The *ameba* does not have any cilia. It moves about in a different way. The ameba bulges out at one point

AN INVESTIGATION into Life in a Drop of Pond Water



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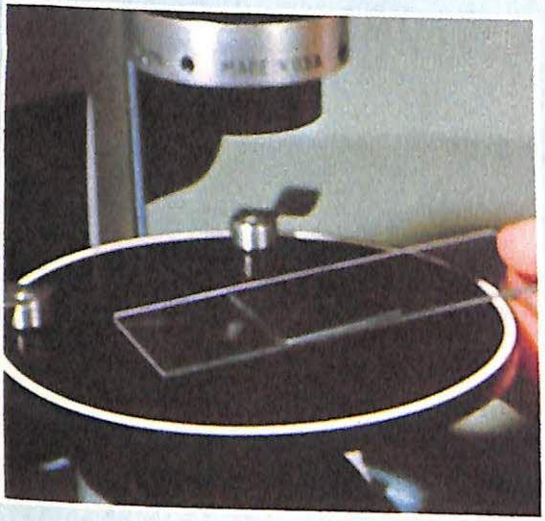

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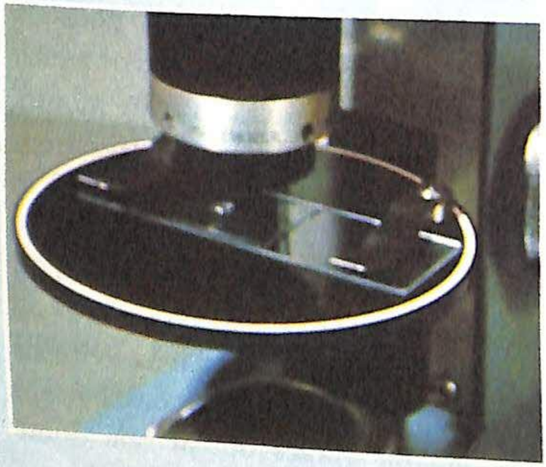

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Needed: a microscope, two glass slides, two cover slips, a medicine dropper, a small jar of pond water, and mud from a pond

Take some pond water from the surface with the medicine dropper. Place a drop on a slide. Try to place a cover slip on the drop so that no air bubbles are trapped under the cover slip. (Don't be discouraged if you don't succeed the first time—it takes practice.) The cover slip will flatten the drop and prevent the lens from getting wet. ■ Put the slide under the lens. ● Bring the microscope lens down close to the slide. Then put your eye to the eyepiece and move the lens *away* from the slide to focus the microscope. ▲

Study the living things in the drop. Are any of them like those shown in the illustration on pages 168–169? Observe how they move and how they feed.

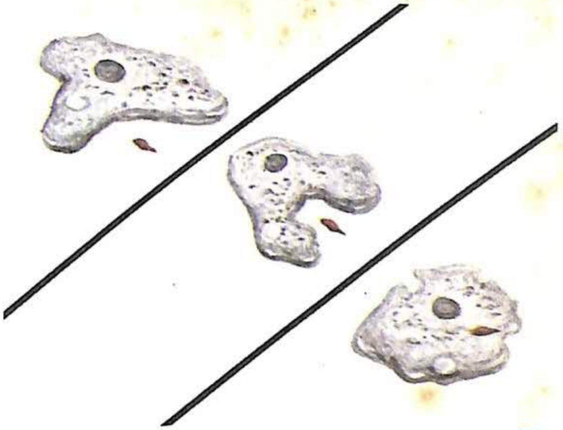
Place a drop of water from the surface of the mud on a slide. Cover it with a cover slip. Explore it. Are there living things in it that were not seen in the first drop?

As you explore, you may well encounter wild animals not illustrated here. A book like *How to Know the Protozoa,* by T. L. Jahn (W. C. Brown, Dubuque, Iowa, 1949) will help you to identify them.

into a kind of finger. The finger grows as the ameba's cytoplasm flows into it. Thus the ameba moves in the direction of the finger. An ameba can swallow a smaller animal or a plant by flowing around and over it.

These are only a few of the animals that can be seen in a drop of pond water. Like the animals in a forest or jungle, they feed on each other. They feed, grow, and reproduce in their own little world.

Get a better look at the living things in your jar of pond water by doing the investigation on the opposite page.



One Cell Can Be Enough

Think of a mouse and a paramecium.

A mouse is a complete living thing, an **organism.** It is an organism made up of millions of cells: muscle cells, nerve cells, blood cells, and many other kinds of cells. A mouse is a many-celled organism.

A paramecium is a complete living thing, too. A paramecium is an organism. But it is made up of just *one* cell. A paramecium is a single-celled organism. For a paramecium, one cell is enough. Just as the yeast is a single-celled plant, one cell is enough for a paramecium, an animal.

What is the difference between a single-celled animal like a paramecium, and a single animal cell, such as a muscle cell in the mouse?

The paramecium can get its own food. The muscle cell in the mouse depends on blood to bring it food.

The single cell of the paramecium can move about on its own. But a single muscle cell of the mouse can move only along with millions of other muscle cells.

Single-celled animals like the paramecium carry on all life activities in one cell. *A single-celled animal is a complete organism.* But a muscle cell is only one kind of cell in a many-celled animal like the mouse. *A single animal cell is only part of an organism.*

Single-celled animals belong to a group known as **Protozoa** (prō′tə-zō′ə). The ameba is a protozoan; it belongs to the Protozoa. The stentor and the vorticella, and other one-celled animals are protozoans. In fact there are more than 15,000 different kinds of protozoans, or single-celled animals.

BEFORE YOU GO ON To help fix the concepts of this section in mind, answer these questions.

1. What are the differences between a single animal cell such as a cheek cell, and a single-celled animal such as an ameba? Give as many differences as you can.

2. What are the differences between a many-celled organism such as a mouse, and a single-celled organism such as a paramecium?

USING WHAT YOU KNOW

1. Which of these two cells is *part* of an organism? Which is a *complete* organism?

muscle cell vorticella

2. Are these two living things the same or different? How?

single animal cell single-celled animal

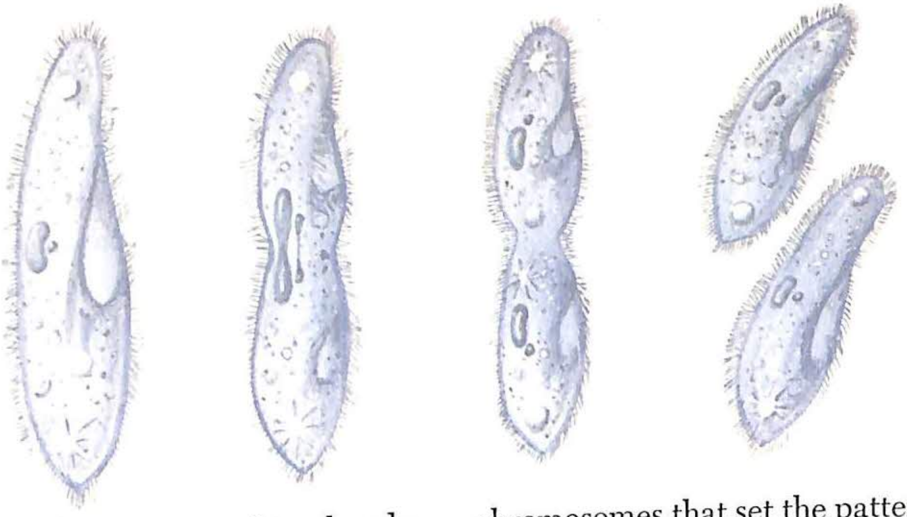
ON YOUR OWN Grow your own protozoans; see page 168 for a method of growing them. How many different protozoans can you grow?

7. Like Begets Like

Spallanzani (späl′län·dzä′nē), the Italian scientist, seemed to be doing something silly. He would put a drop of water on a glass slide. Then another drop on another slide. Then another . . . and another . . . and another. . . .

But Spallanzani had an idea. He reasoned this way. Where do single-celled organisms come from? If he could only get just *one* organism in a drop of water! Then he would be able to watch it closely and perhaps find out. So he put drop after drop of water on slides. At last he caught just one single-celled organism in one drop.

He watched the organism carefully through his microscope. It began to pinch in the middle. The pinch deepened. The organism pinched into two organisms! So that was the way it reproduced! One divided into two. Then two could divide into four. Four could divide into eight, and so on. No wonder that the water was crowded with organisms in a while, since they could divide so.



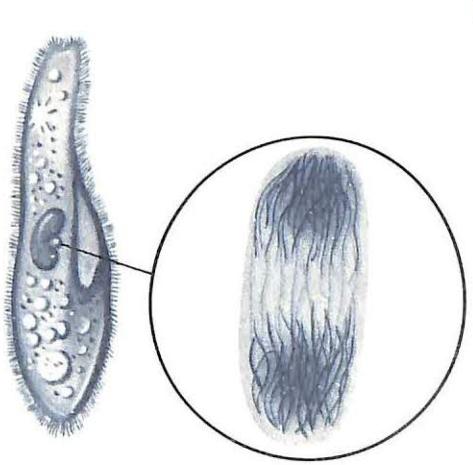
Of course you know this already. But scientist Spallanzani was working in the year 1750. His discovery was a great one.

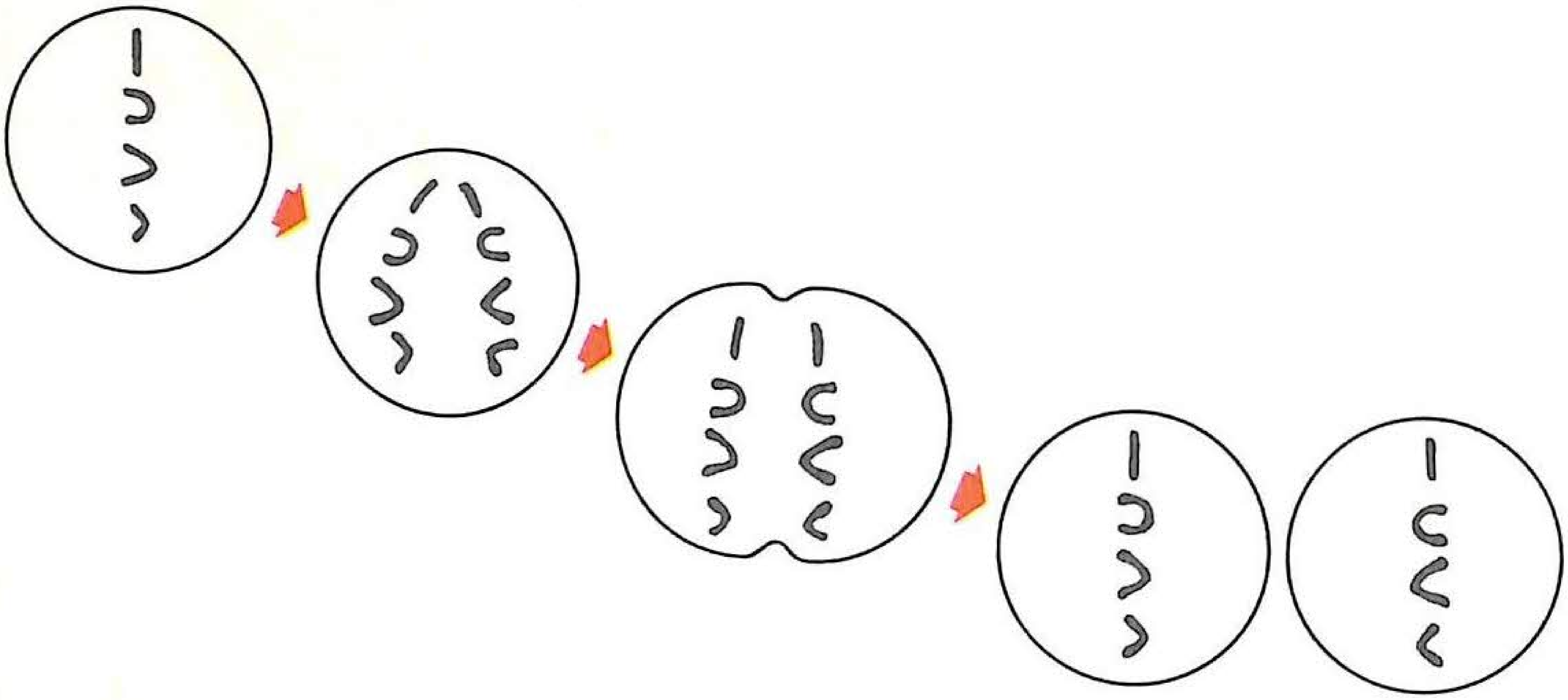
This peanut-shaped creature is a paramecium dividing in two. ■ When paramecia are well fed, they can reproduce themselves. A paramecium swimming about becomes pinched in the middle. In a few hours there are two paramecia, looking just like each other. This kind of cell division is called **fission.** Protozoans generally reproduce this way—by fission. Fission means "dividing into equal parts." When a yeast cell buds, it does not divide in equal parts. So yeast cells do not undergo fission. Most protozoans do.

Setting the Pattern

By fission, one protozoan produces two protozoans. They are like each other and like the parent. They are alike because of tiny bodies called **chromosomes** (krō′mə·sōms). It is the chromosomes that set the pattern, and make the new protozoans look like the old ones.

Suppose that you could examine a paramecium as it is dividing. Within it you would find these threadlike bodies. ● These are the chromosomes. It is because of them that an ameba looks like an ameba. The chromosomes of a paramecium have a substance in them that gives the paramecium its shape, its cilia, and its other parts. How do scientists know that it is the





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chromosomes that set the pattern? Scientists have managed to change the substance in some chromosomes and have seen the organism change.

In *your* cells there are chromosomes. Your chromosomes have a substance in them that, somehow, is responsible for your characteristics. Your chromosomes set the shape of your face, the color of your eyes, your hair, your skin. Your chromosomes determine the kind of nose, lungs, heart, and brain you have.

Passing the Pattern Along

How are characteristics handed along from parent to offspring?

When a protozoan divides, its nucleus divides, too, as you know. Before the nucleus divides, however, the chromosomes inside the nucleus duplicate themselves. When this happens the substance in each chromosome also duplicates itself. This substance is called DNA for short. (Its chemical name is not really needed at this point.)

Suppose a protozoan has four chromosomes shaped like these. ■ Each chromosome duplicates itself. Now there are four *pairs* of chromosomes. When the protozoan divides, each offspring gets one chromosome from each pair. Thus each offspring gets four chromosomes just like the parent's chromosomes. Each of the four chromosomes has the DNA of the parent. The two offspring are twins.

When the protozoan divides, the parent passes on to its two offspring an equal number of chromosomes. Each protozoan which comes from the parent has the *same* kind of chromosomes. Each has the *same* DNA. So the young protozoans are twins. Fission produces twin protozoans.

A paramecium actually has 16 chromosomes. A vinegar fly has 8 chromosomes. An onion has 16 chromosomes. You have 46 chromosomes.

The study of chromosomes is one of the most important tasks of scientists. There is a great deal still to be discovered about how chromosomes duplicate themselves. For instance, no one yet knows *how* the DNA in a chromosome helps to make a brain, or an eye, or eye color. The evidence is, however, that the chromosomes are responsible for the patterns of living things. The chromosomes of an apple tree make it produce apples, not pears. The egg of a hen produces a chick, not a duckling or a turtle. Whatever it is that sets the pattern for a chick is in the DNA within the chromosomes of the egg. Thus the pattern is set. Thus the pattern is handed along from parent to offspring, by duplication of the DNA in the chromosomes.

BEFORE YOU GO ON

Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A paramecium divides by
   a. budding
   b. fission

2. The paramecium, a single-celled animal, divides in two to reproduce itself. It has 16 chromosomes. Each of the two single-celled animals which is produced has
   a. 8 chromosomes
   b. 16 chromosomes

3. Each of the two offspring from one parent paramecium has an equal amount of
   a. ATP
   b. DNA

4. The substance that makes an apple tree produce apples, not pears, is
   a. DNA
   b. ATP

USING WHAT YOU KNOW

1. What is the difference between *budding* and *fission*? Include a drawing in your answer.

2. Suppose a paramecium divides by fission once a day. During the day all the offspring grow to full-sized paramecia. They too divide. How many paramecia would there be in 10 days?

3. What is meant by "like begets like"? Give examples using a

yeast cell paramecium robin

ON YOUR OWN Perhaps you would like to read more about *chromosomes.* Where would you look? in the dictionary? in an encyclopedia? in a book on biology? Biology is the science in which living things are studied.

8. From One Cell

Did you know that an egg is just one large cell?

A chicken's egg is one large cell. So is a frog's egg. So is a robin's egg.

Surely this is a remarkable thing, when you stop to think of it. A chicken, or a frog, or a robin, is made up of millions of *different* cells. Yet all these different cells come from just one dividing cell, the egg.

How does a single cell produce many different cells? You can see for yourself how this happens, in a frog. Try the investigation on the opposite page.

A Frog Develops

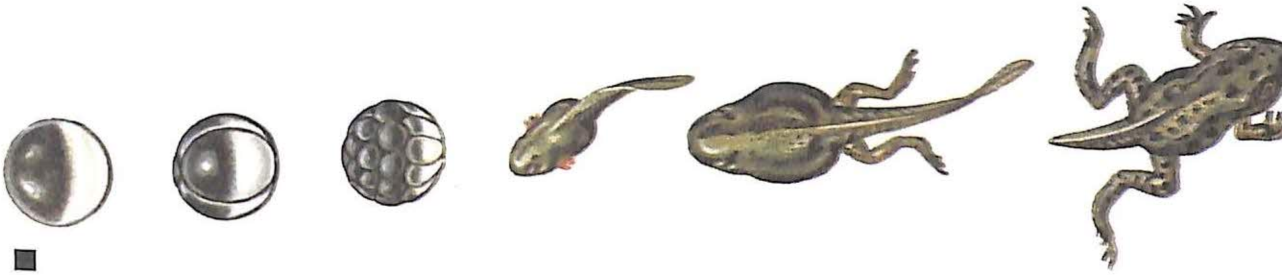
The egg of a frog is just one cell. However, it is a special kind of cell. When the egg cell begins to divide, it doesn't form more egg cells. *The egg cell forms many different kinds of cells.* It forms skin cells, muscle cells, bone cells, nerve cells, blood cells. These cells form the different parts of the frog's body. The different parts do the different things a living thing has to do to live. These different parts are called **organs.** For instance, the heart is an organ that pumps blood. The intestine is an organ that digests food. The lungs, the liver, and the brain are other organs of the body. Each organ does a special kind of work.

However, all these different organs begin with the same cell. All begin with the egg cell.

We have a word that you know well for this forming of more and different cells. Yet you may not have thought of the word in this way. This forming of more cells and different cells is growth.

The frog begins as one egg cell. That cell divides and divides and divides to form many different cells. These cells form organs. Finally a complete living thing is formed, an *organism*. It has grown from one cell.

AN INVESTIGATION into the Growth of a Frog



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Needed: frog's eggs, an aquarium with growing plants, a hand lens

In the early spring frogs gather near ponds. There the female frogs' eggs are laid, in bunches. If you live near a pond, collect some eggs that are ready to develop. They will have black dots in the egg mass.

Bring some eggs to class and place them in an aquarium with growing plants. If you separate a few eggs from the larger mass, you can watch a single egg develop. ■ See if your observations agree with these.

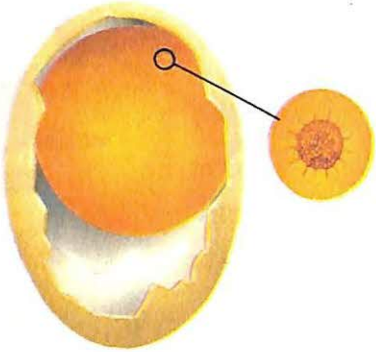
First, the single egg cell divides again and again. It forms a ball of cells.

The ball of cells lengthens. The beginnings of eyes can be seen, and so can a tail.

The tail gets longer, and legs show. Gills form and grow. They begin to take in oxygen from the water.

The single egg cell has become a tadpole. The tadpole lives in water, eating plants and remains of dead animals.

The tail gets shorter and disappears. The tadpole becomes a frog that lives on land. The single cell has become millions of different cells.



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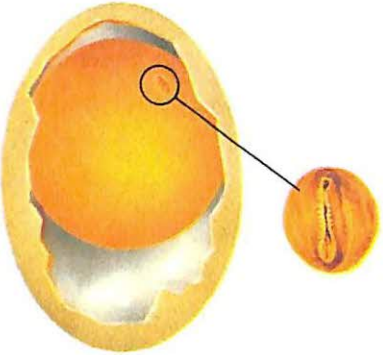

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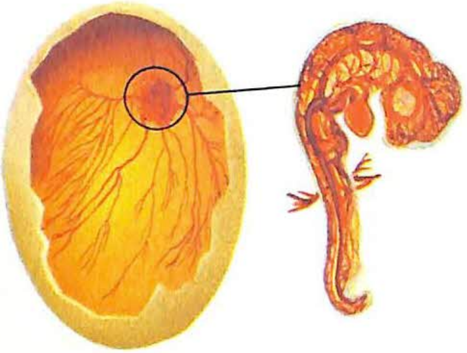

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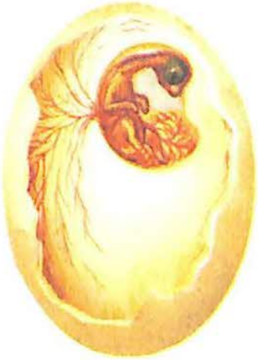

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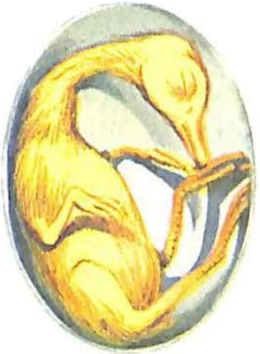

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A Chick Grows

What happens inside a hen's egg to change it into a living bird? Scientists have watched as an egg cell divides. This is what they have seen.

When the egg is laid, the single cell has already begun to divide into many cells. ■

One day later different tissues are beginning to appear. ●

Three days later a beating heart is pumping blood. ▲

Can you see the beginnings of legs and wings, 7 days later? ◆

The chick is almost fully formed by the 18th day. ★

On the 21st day the young chick pecks its way out of the egg. ◈ It is not yet ready to fly. In fact, a chicken is a bird that does not fly very well.

Protecting the Young

In early spring, robins build their nests. A male and a female robin collect twigs and mud and build a nest shaped like a bowl. ◎ (Other kinds of birds build other kinds of nests. The robin always builds a robin's nest, not an oriole's nest, or an eagle's.) In the nest the female robin lays from four to six speckled blue eggs.

All the time a robin's egg is developing, it is kept warm and protected by the parents. How different this is from what happens to a frog's egg! Most frogs do not protect their eggs. Their egg cells divide and develop in the water. Most of the eggs, and most of the young, are eaten by other animals.

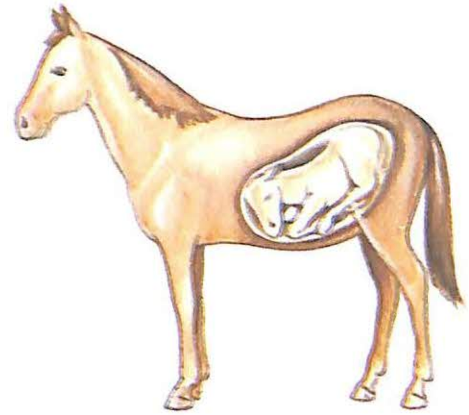
The frog is a cold-blooded animal. Its temperature is the same as the temperature of its surroundings. A frog's egg can develop in water that changes temperature. It doesn't have to be kept at an even temperature. However, a long freeze may kill frogs' eggs.

◎

A bird is a warm-blooded animal. Its body temperature is about 104° Fahrenheit. Its eggs have to be kept at a fairly even temperature. The robin sitting on the eggs supplies warmth for the robins developing inside the eggs.

Have you seen a male robin standing guard while the female sits on the eggs? He will chase off birds and animals that try to catch the mother bird or eat the eggs. The robin's eggs have a better chance of hatching than do the eggs of the frog, because they are protected by the parents.

The young of some animals have even better protection, because the eggs develop inside the mother. The eggs of an animal such as the mouse, the rabbit, the horse, or the elephant begin to divide inside the mother's body. Within a female horse, for example, dividing cells form different organs of the young colt's body. The forming colt is protected from harm there. It gets food substances and oxy-



gen from its mother. From the mother the colt gets the substances that its dividing cells must have in order to grow and divide.■ The wastes that the colt's dividing cells give off are taken away by the mother's body.

After the colt is born, its mother nurses it with milk. It keeps on growing. In time it becomes full-grown.

Scientists have watched many kinds of cells dividing. Scientists do know how cells divide. But how can one egg cell form many different kinds of cells? So far scientists have found out very little about that. They know even less about how such cells join together to form different organs!

There is still a great deal for scientists to find out.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The egg cell of an animal like the grass frog or the robin divides to produce many cells. These cells are

a. all the same b. not all the same

2. The egg cell of an animal such as a bird or a frog develops into a

a. ball of cells b. tadpole

3. We call the process of an egg cell forming more cells

a. growth b. fusion

4. Unlike frogs and birds, some animals develop from the egg

a. outside the mother b. inside the mother

B. Write a paragraph or two in answer to this question: "How Does an Egg Produce a Complete Living Thing?"

USING WHAT YOU KNOW

1. Tell the story of the growth of a frog from the egg.
2. Tell the story of the growth of a bird from the egg.

ON YOUR OWN

Study the growth of a plant from seed to complete organism. One way to do this is to soak a dozen bean seeds or corn grains overnight. Then plant them between a blotter and the glass in a jar. ● Keep the blotter damp.

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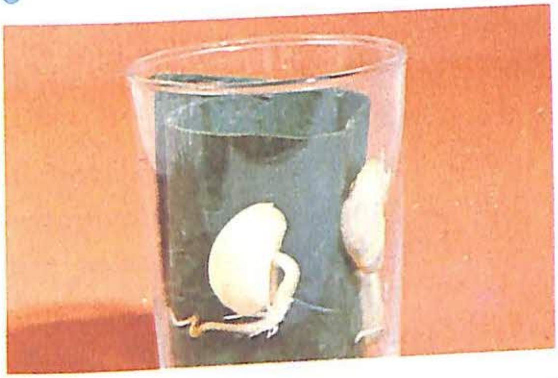

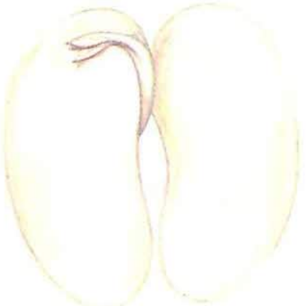

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Every day take a bean apart. Draw the steps in the growth of a bean. The first drawing might look something like this one of a bean seed, a day after being soaked. ▲

9. From Earth into Cell

A seed of wheat is planted. The soil is watered. The seed cells start dividing. Roots grow down. Through the root hairs, substances in the soil enter the plant. A stalk rises above the soil and puts out leaves. Through the leaves, gases in the air enter the plant. The seed has become a wheat plant.

All this begins with one cell, dividing and dividing. . . . Where does a growing plant get the substances that give it energy? The substances come from the soil and from the air. So the plant must have in it some elements and compounds from the Earth's crust, and it must have some elements and compounds from the air as well.

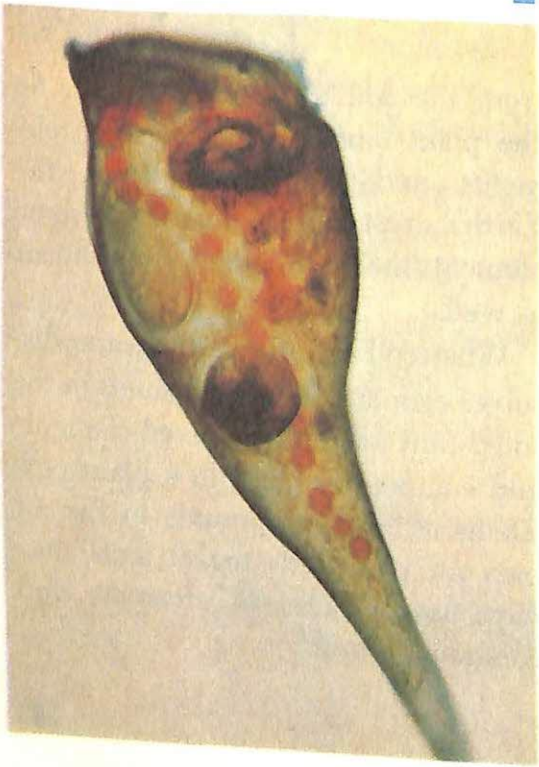
When soil is watered, the water dissolves elements and compounds in the soil. Many of these dissolved elements and compounds get into a plant cell. Elements and compounds in the air pass into plant cells, too. So a cell may have many different elements and compounds in it.

Inside the cell, food substances are oxidized as part of the cell's energy process. As this happens many new compounds are formed.

The living stuff in the cell is made up of various elements and compounds. The living stuff in the cell is called **protoplasm.** Most parts of a cell are made up of protoplasm. The nucleus, the cytoplasm, the cell membrane, and the chloroplasts are all made up of protoplasm. The living stuff inside this stentor, for example, is protoplasm. ■ Protoplasm is the living stuff in cells. Protoplasm is the stuff that life is made of.

What kinds of compounds are there in protoplasm? To see for yourself, try the simple chemical tests in the investigation on the opposite page.

■



Protoplasm and Its Compounds

Protoplasm has a good deal of **protein** in it. Proteins are compounds made up of carbon, hydrogen, oxygen, and nitrogen. (Some proteins contain sulfur and phosphorus as well.) Meat, fish, and cheese are made up mainly of protein.

A test for protein is its smell when a substance burns. If a feather or some hair is burned, the odor of burning protein can be detected.

Another group of compounds found in protoplasm is called **carbohydrates** (kär′bō·hī′drāts). Carbohydrates are made up of carbon, hydrogen, and oxygen. They do *not* have nitrogen in them, as the proteins do. When carbohydrates are completely burned, carbon dioxide and water are produced. If the carbohydrates are incompletely burned, black carbon remains and may be seen.

Starches and sugars are carbohydrates. As you know, starch turns blue-black when iodine is placed on it. Test for starch with iodine.

Not all compounds that turn black and give off water when burned are carbohydrates. Some are **fats.** Butter is a fat. Nuts have fat in them. So do meat and milk. Cells make fats, and protoplasm has fat in it.

Fats are compounds of hydrogen, carbon, and oxygen, as are carbohydrates. But these elements are combined in different ways in fats and in

AN INVESTIGATION into Testing for Compounds in Protoplasm

Needed: a bowl, two sheets of aluminum foil, a feather, some hair, dry cereal such as cornflakes or rice flakes, a pat of butter, a peanut, a glass plate, brown paper, matches

Put aluminum foil on the bowl as shown. ■ Place the feather on the foil. Your teacher will light the feather. Notice the strange smell as the feather burns.

Burn some hair on the foil. Hair, too, has this odor.

Both feather and hair have nitrogen and hydrogen in their protoplasm. What color does the burning feather turn? This shows that carbon is present as well. This compound of nitrogen, hydrogen, oxygen, and carbon is called protein. The smell given off when a substance burns is one test for protein. Both the hair and the feather contain protein.

Put aluminum foil on the bowl. Place the cereal flakes on the foil and light them with a match. Hold the glass plate over the flakes as they are burning. What collects on the glass? ● Drops of water collect, and the burning flakes turn black. Whenever a substance is burned incompletely and only carbon and water come from it, it is not a protein. In this case, it is a carbohydrate.

When carbohydrates are burned incompletely, carbon is the result. Water is given off as well.

Rub some butter on the brown paper. It makes a shiny spot, through which some light can pass. This is a test for fat. It shows that there is fat in butter. Rub the peanut on the brown paper. Does it make a fatty spot?

Additional Investigation: Shape some aluminum foil into a cup. Put a small lump of sugar in it and hold the cup over a flame with a pair of pliers or tongs. Predict what will happen as the sugar burns. Test your prediction.

■

carbohydrates. The number of carbon, hydrogen, and oxygen atoms in the molecules differs. The arrangement of the atoms differs, too.

When a feather or some hair is burned, ashes are left. When a bone or some wood is burned, ashes are left. The ash is made up mainly of **minerals** found in protoplasm. The minerals are salts, like common salt, or compounds of calcium and phosphorus. They enter the plant through its root hairs.

The minerals in protoplasm are almost always dissolved in water. In fact, protoplasm may be as much as 99/100 water. Different kinds of protoplasm may have different amounts of water. The protoplasm of an egg has much less water in it than has the protoplasm of a watermelon.

In protoplasm, the living stuff in a cell, there are five main kinds of compounds:

proteins
carbohydrates
fats
minerals
water

Let's go a little further. What makes up all elements and compounds? What are the building blocks? Atoms, of course. Atoms are the building blocks of protoplasm, as they are of all matter. In a cell, atoms are combined into different kinds of molecules to make protoplasm.

Many scientists call cells the building blocks of living things. Certainly the cell is the center of the process which gives us energy. Isn't a cell like a tiny factory too? It breaks down some substances and puts together other substances.

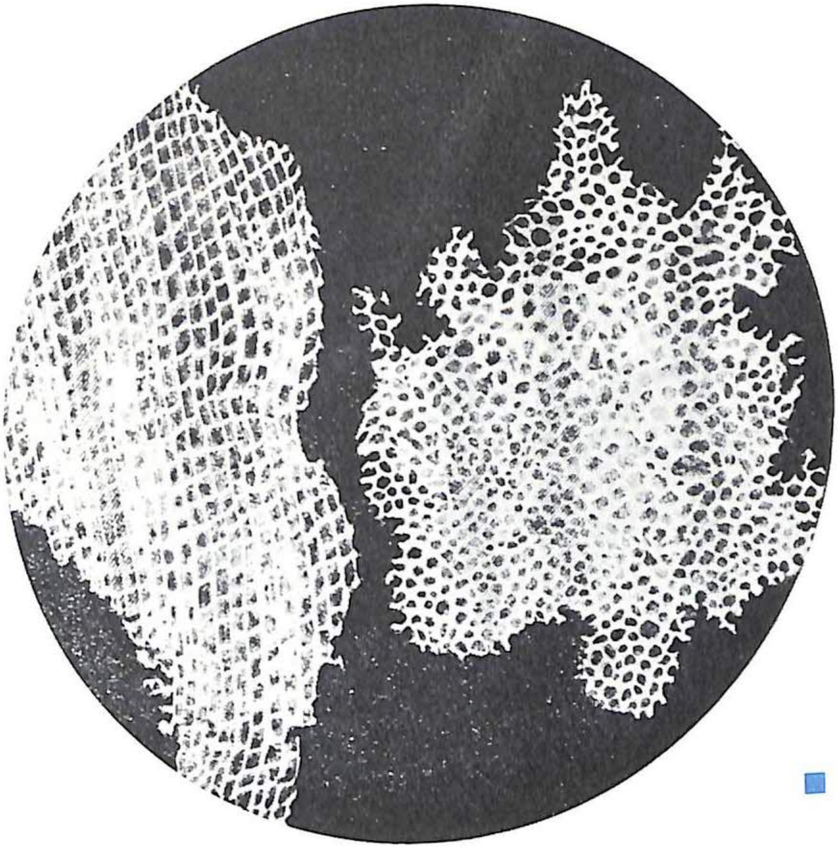
Scientists still know very little about just how a cell does all these things. There is a great deal yet to be found out.

BEFORE YOU GO ON

1. What are the main kinds of compounds found in cells?
2. Where do these compounds come from?
3. What are the building blocks of these compounds?

USING WHAT YOU KNOW

Glucose is a kind of sugar. Like all sugars, glucose is a carbohydrate. Would a test for protein work on glucose? Why? Would a test for fat work on this sugar? Why?



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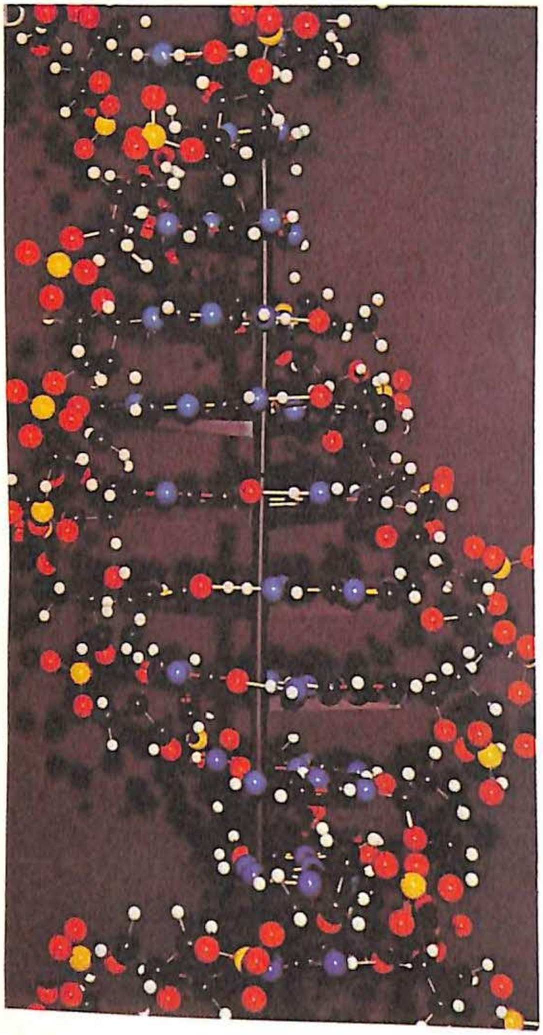
10. The Main Concept: Cells as Building Blocks

It took many years of work to find out that living things are made up of cells.

About 300 years ago an English scientist named Robert Hooke was looking at all sorts of things through a new invention called the microscope. He examined the point of a needle, the edge of a razor, linen cloth, snow, bubbles, plants, seeds, insects, fleas, molds, and many other things. (The first microscopes were sometimes called "flea glasses" because people liked to look at fleas through them.) Hooke examined some cork, and was delighted to see that it was made up of little boxes.■ He called the boxes cells. He was looking at cell walls, really, for in cork the protoplasm has disappeared. Only the cell walls are left.

It took almost 200 years of work after Robert Hooke's discovery to convince scientists that *all* living things are made of cells, and that cells do the work of a living thing.

For instance, in 1839 two German scientists, M. J. Schleiden and Theodor Schwann, stated their famous cell



■

theory. Their cell theory was that all living things are made up of cells. Today, more than a hundred years later, we know that cells are the building blocks of living things.

We know more. We know that each cell is a kind of energy machine. Inside a cell, ATP is broken down to yield energy for the cell's work and growth. Then the ATP that has been broken down is built up again. The energy to build up the ATP comes from glucose and other food substances.

We know also that cells are made up of elements and compounds found on the Earth. Cells take in these elements and compounds from soil, water, and air. The protoplasm in a cell uses these elements and compounds. The protoplasm makes new protoplasm.

All protoplasm is not the same. When *you* eat food, your cells and protoplasm make more of *you*. When a cat eats food, its cells make more cat cells and protoplasm. The protoplasm in a bean cell makes more bean protoplasm.

We are all different. Each of us has different protoplasm. Yet we are alike too, for we have the same kinds of cells. Each of us has muscle cells, nerve cells, blood cells, skin cells, bone cells. Each of us has these different kinds of cells grouped in organs.

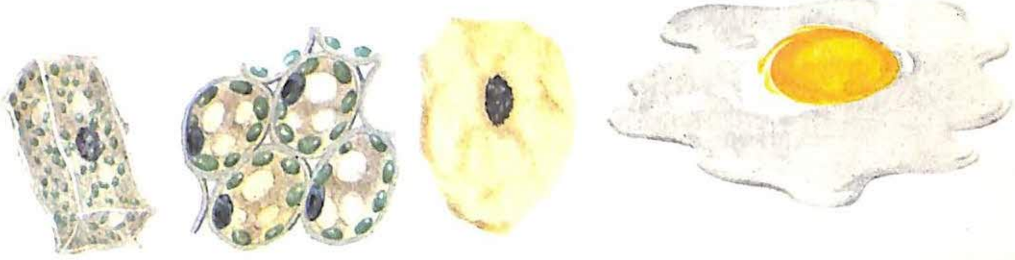
Cells are the building blocks of living things. Within a cell of each living thing are chromosomes. Within each chromosome is the substance DNA. (Here is part of a DNA molecule model. ■) DNA has in it the pattern of that living thing. When a cell begins to divide, to reproduce, its chromosomes duplicate themselves. Because the chromosomes and their DNA duplicate themselves, living things receive the characteristics carried by their parents.

Fixing the Main Concepts

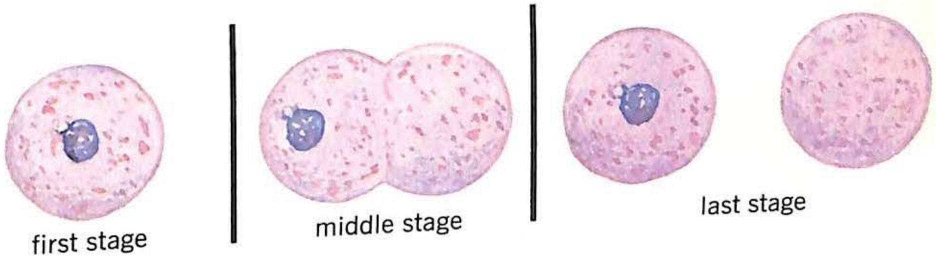
TESTING YOURSELF

A. Test your understanding of important concepts in this unit by doing these problems.

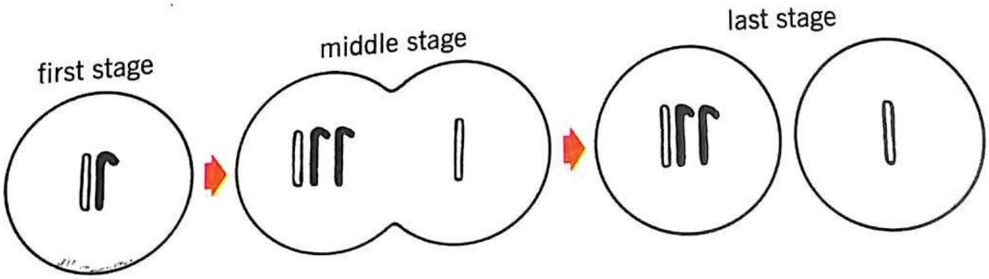
1. Here are diagrams of some common cells. Which cells are from a plant? which from an animal?



2. a. What is *wrong* in this diagram of a dividing cell?
b. Why is the diagram wrong?



3. Here is a diagram of a dividing cell and its chromosomes. What is *wrong* here? Why is it wrong?



4. Put a lump of sugar in some water, and leave the solution open to the air. After a while bubbles of gas come from the water. You know that yeasts and molds float about in the air.

a. What might the bubbles be?
b. How could you test your guess?

B. Test your knowledge with this quick check.

1. A part that is not found in an animal cell is the
   a. nucleus
   b. cell membrane
   c. cell wall
   d. cytoplasm
2. A part of a cell which many plants have but a cell in a frog does not have is the
   a. nucleus
   b. cell membrane
   c. chloroplast
   d. cytoplasm
3. The part of the cell which has in it the pattern of growth which the living thing follows is the
   a. cell membrane
   b. cell wall
   c. chloroplast
   d. chromosome
4. The substance ATP, in the cell, has to do mainly with
   a. energy
   b. shape
   c. size
   d. color
5. The living thing which is *not* like the other three is
   a. paramecium
   b. ameba
   c. stentor
   d. yeast

ON YOUR OWN In the Laboratory

Some foods are now sold dehydrated—that is, the water in the cells of the food has been removed. Could you use this fact to find out about how much water was originally in the cells of some plant?

Cut some half-inch cubes out of an apple. Slowly dehydrate them with heat. How can you find out how much water they lose?

FOR YOUR READING

These books will help you explore the building blocks of living things.

1. *Through the Magnifying Glass,* by Julius Schwartz, published by McGraw-Hill, New York, 1954. Practice in using a magnifying glass is given in this interesting book. Once you have learned how, you will be able to examine many living things.

2. *Bits That Grow Big,* by Irma E. Webber, published by W. R. Scott, New York, 1949. This book contains stories about growth. You will find the living things in these stories all around you.

GOING FURTHER

What is a good way of growing the single-celled animal, the paramecium?

The best way to get some paramecia is to collect a pint of pond water in the spring or summer. Add to the water a bit of hard-boiled egg yolk the size of a pea. Crumble the egg yolk between your fingers as you drop it in the water.

Bacteria will grow on the food of the egg yolk. The paramecia will feed on the bacteria. Paramecia have been grown on rice and on wheat, as well as on egg yolk.

On which of these foods do paramecia grow best?

How will you know when the paramecia are growing best? We suggest you count them. A paramecium is large enough to be seen with a 150X microscope. One way to find out when the paramecia are growing best is to count how many are in a drop of the water.

Plan your investigation. Perhaps you would like your teacher to read over your plan. Share your findings with your classmates.

CONCEPTUAL SCHEME

A living thing is the product of its heredity and environment.

(*Text pages 190–225*)

UNIT CONCEPT

The cell is the unit of structure and function; a living thing develops from a single cell.

A Preview of the Concepts

Unit Five

BUILDING BLOCKS OF THE BODY

The child gains an understanding of cells, the building blocks of the body. He develops the important concept that the cells of his body work together in teams or systems, each system adapted to perform a particular function.

A VIEW OF THE UNIT

With this unit, children move from the cell to the organism and study their own organ systems to learn how they take in matter—food and air—in order that each cell in every organ in every part of the body is supplied with the substances it needs to carry on the cell energy process. Without food, no energy can be supplied to build up ATP and the cell energy process runs down. Without oxygen, food cannot be oxidized to liberate its energy. In a short time, life processes cease. Thus, there is an interchange of matter and energy with the environment.

A basic idea of this unit is organization—organization of cells into increasingly complex structures having specific functions in the work of the total organism. Just as the child studied cell functions in Unit Four, he now studies the functions of the organs and the total organism.

The alert child may see that processes at work in the physical environment are also at work in his body. For example, children have met earlier in the text the concept of oxidation, the combining of substances with oxygen, which is a chemical change. At one time, a rapid oxidation was referred to as burning with a flame, and slow oxidation as burning without flame. Scientists no longer speak of slow oxidation as burning. Oxidation in body cells is much more than mere release of energy from a chemical combination; it encompasses the entire cell energy process in which energy released by the oxidation of glucose aids in building up ATP, and the breaking down of ATP releases energy for the cells to do work. How the child's body—and by implication, the body of any organism—obtains its oxygen by intake of air and its diffusion through membranes into the blood is inherent in the concept developed in the first section.

Breathing, a physical process introduced earlier, is seen in operation. The means of obtaining air is related to the concept of air pressure. The environmental (atmospheric) pressure is about 14.7 lbs. per square inch. Within the lungs, the upward movement of the diaphragm in exhaling creates a pressure greater than atmospheric pressure, while the downward movement in inhaling creates a pressure inside the lungs less than atmospheric pressure. The text illustrates this change of pressure with a physical model.

In Section 2, another concept of physical change is reviewed in the chewing of food particles. Every child who has seen a fire built knows that small particles kindle faster than large ones. He may not know, however, that the smaller particles give a greater surface area to speed the chemical change of oxidation of the fuel substances. Chewing changes the size of the particles (a physical change). The digestive juices in the mouth and other parts of the digestive tract can act more rapidly (chemical change) on the smaller food particles so that they can dissolve.

Dissolving is, of course, a physical change. The breaking down of food into smaller and simpler substances so that it can pass through a membrane is the concern of Section 2. Molecules of matter—in food and oxygen—are seen to make up the cells of an organism.

Thus far, children have not directly studied differentiation of cell structure in relation to function, although some may have inferred it. They now examine the major types of body cells and note the similarities in structure and the differences in function that underlie the shape of cells and their organization into tissues and organs. Each cell has identical structures to engage in the cell energy process; but, in each organ, cells are differentiated in form and shape for a particular function. This is the central concept of Section 3.

In Section 4, the concept of structures organized for function is extended from organs to organ systems. Each system is studied briefly. Under the digestive system, mention is made of enzymes and of glands that secrete substances that aid in the digestion of food. The enzyme in saliva (ptyalin) starts the breaking down of carbohydrates. Pepsin produced in the lining of the stomach, with hydrochloric acid in the gastric juices, aids in breaking down proteins. The liver makes bile which helps to break down fats, and the pancreas secretes three enzymes (trypsin, steapsin, and amylopsin) which help digest fats and proteins in the small intestine and continue the work done by the saliva. While it is not important that the child know this much detail at this time, you may wish to give interested children a lead for research.

Using Analogies

Several analogies relating body structures to a building and to machines are offered. To make such analogies more complete, it may be well to point out that energy must be supplied these structures if they are to operate. We supply that energy. For the body structures to work, the cell energy process supplies the energy. Foods (matter) are changed into the matter of the body (its structure), and energy is released for the total organism to do work (its functions).

Section 5 relates all the concepts to the central idea that each total organism is adapted by structure to function in its environment; that is, that living things are products of their heredity and environment.

SUPPLEMENTARY AIDS

Films

All films are in color. Names and addresses of suppliers are on page F–25.

Animals Breathe in Many Ways (11 min.), F.A. Animals must breathe in order to live. Animals breathe in many different ways—directly through body covering, gills, tubes inside of bodies, and through lungs. (Intermediate)

How the Body Uses Energy (15 min.), McGraw-Hill. Energy is required to maintain all physiological processes. Digestion—reduction of complex molecules that can be absorbed into blood stream; respiration—getting oxygen into blood stream; muscles—production of heat and lactic acid in a contracting muscle; nervous system—shows energy is used to generate electrical impulses in the brain. (Advanced)

How Your Bodies Fight Disease, E.B.F. Illustrates by animation the body's three lines of defense against bacterial disease: skin and mucous membranes; the lymph nodes, antibodies, and white corpuscles in the blood stream. (Intermediate)

Filmstrips

Health Adventures (9 strips, color), Jam Handy. Series showing how the human body works and why health rules are important.

1. *How Your Ears Work* (61 frames); 2. *Sleep and Rest* (57 frames); 3. *Your Bones and Muscles* (71 frames); 4. *Your Eyes at Work* (67 frames); 5. *Your Food and Digestion* (61 frames); 6. *Your Heart and Lungs* (74 frames); 7. *Your Nose and Throat* (64 frames); 8. *Your Skin and Its Care* (68 frames); 9. *Your Teeth and Their Care* (63 frames). (Intermediate)

Walt Disney, This Is You, EBF, 1958. Each filmstrip in the series has 50 frames, and each covers an important aspect of human biology or health. Developed with cartoons featuring Jiminy Cricket. 1. *You the Human Being.* Greatest difference between man and animals is that man can think; 2. *You and Your Five Senses.* Man is able to think and reason; importance of each of five senses to animals and to man; 3. *You and Your Eyes.* Shows how the eye is like a camera; how it adjusts to light. How to protect your eyesight; 4. *You and Your Ears.* Explains how you hear; parts of ear, purpose of each part. The ear helps you hear, also helps you keep your balance; 5. *Your Senses of Smell and Taste.* Comparison of importance to animals and to man; 6. *Your Sense of Touch.* How useful to man; 7. *You and Your Food.* Everything alive needs food; a balanced diet; kinds of foods; 8. *You the Living Machine.* Energy for growth provided by foods. Shows process of digestion; absorption of digested food into blood vessels and function of heart in pumping blood to all parts of body. (Primary; Intermediate)

Starred titles are especially useful for this unit and grade. Names and addresses of publishers are on page F–24.

All About the Human Body by Bernard Glemser, Random House, 1958. The anatomy and physiology of the body are described in simple terms. Good diagrams enhance the narrative and accurate concept development. (Average)

°*For Junior Doctors Only* by Helen Jill Fletcher, Bobbs-Merrill, 1961. Provides basic facts about the structure and functions of the human body. Conveys a sense of appreciation of the wonderful design of the body and responsibility of individuals to keep it in good working order. (Average)

°*The First Book of the Human Senses* by Gene Liberty, Franklin Watts, 1961. Describes what our many senses are, what they do, and what they do for us. Includes many more senses than the familiar ones of sight, hearing, touch, smell, and taste. (Average)

Why You Are You by Amram Scheinfeld, Abelard-Schuman, 1958. Consists of introductory treatment of heredity and genetics. Excellent beginning reading on these complicated subjects. (Average)

The Brave Gives Blood by Philip and Miriam Eisenberg, Julian Messner, 1954; paperback published 1958 by TAB Books, an affiliate of Scholastic Magazines, for distribution through Arrow Book Club. Billy and Frank, with the Indian counselor at Camp Takanasee, have many adventures collecting small animals as part of a strange contest. The boys learn important physiological facts about themselves and about the small animals; particularly about blood. (Easy)

The Wonder That Is You by Charles Gramet, Abelard-Schuman, 1962. Physiology of the human body is interwoven with description of structure. Emphasis is given to growth factors and to the relationship of activities—such as eating and playing—to the functioning of the organs of the body. (Average)

Your Body and How It Works by Patricia Lauber, Random House, 1962. Simplified descriptions of the structures and functions of the human body. The cell is described as the building block of the body. The process of reproduction is dealt with lightly as cell division. (Easy)

Wonders of the Human Body by Anthony Ravielli, The Viking Press, 1954; paperback by Scholastic Book Services. The skeleton, the muscles, the brain, the nervous system, and the digestive system are described with interesting narrative and action drawings. The structure and movements of the body are compared to various machines. (Advanced)

Your Food and You by Herbert S. Zim, William Morrow, 1957. Contains information on why we need to eat, what makes up food, how we digest it, and what it does for our bodies. Includes consideration of the reasons behind the need for food. (Average)

INTRODUCING THE UNIT

Read with the children the opening text of the unit (page 191) and encourage careful examination of the illustration and the raising of questions. Out of discussion can come a tabulation of educated guesses in answer to some questions, and deferral of others. Some questions you might use to start the work of the unit: What *does* the work of your body? (Your cells.) What *is* the work of your body? Children's responses may be related, as the unit progresses, to the concept of cell growth—the major work of cells in a child's body.

(Text pages 192–195)

SUBCONCEPT

There is an interchange of matter and energy between the organism and its environment.

Processes emphasized

Investigation (with design of experiment)
Hypothesizing
Theorizing
Inference
Prediction

Section 1: A DEEP BREATH

Children become aware that breathing is essential to the work of our cells. (Breathing provides oxygen that is used in the cell's energy process.)

Introducing the Concept

Touch your skin. It feels warm, doesn't it? Why? What makes your body warm? (Energy from food.) How do you get heat from a log, a lump of coal, a charcoal briquet? (By burning, or oxidizing, it.) How do you get heat from your food? (By oxidizing it.) Can you now answer the question: What is the real purpose of breathing? (To get air to our cells to oxidize food molecules into energy.)

We all breathe for the same purpose—to supply oxygen to our cells. Do we all breathe the same way?

Developing the Concept

Through observation, children infer that rates of breathing may differ.

Rates of breathing. Following the reading of pages 192–193, initiate a class discussion of differences in breathing rates. How many times do you inhale in a minute? Children now will be ready for the investigation (text page 194). Asking the children to study their breathing rates does two things: They discover something about breathing, and they have an objective experience with regard to one of their bodily functions.

The amount of air that can be inhaled is determined by the expansion of the lungs.

Equipment and Materials

. . . 2-quart jar and lid
. . . dish
. . . rubber tubing

Measuring lung capacity. Children may now be interested in measuring their own lung capacity. Fill a 2-quart or gallon jar with water. Cover the opening and invert the jar. Remove the cover under water to retain as much water as possible in the jar. Mark the water line with tape. Now, gently slip one end of the rubber tubing under the edge of the jar. How much water can you blow out? Let several children measure their lung capacity by displacing water with exhaled air. Invite the advice of your school nurse for materials and procedures which will keep the tube sterile for different children. When you finish, will there be exhaled air or ordinary air in the jar? How could you show there is a difference between ordinary air and exhaled air?

Oxygen in exhaled air and fresh air. Collect, underwater, a jar with exhaled air in it. Remove and set upright in plain view and cover it. Bend a pipe cleaner around a small birthday-cake candle. Uncover the jar just enough to lower the lighted candle into it. What happens? Relight it and lower into another open jar the same size. Why does the candle now stay lit for a while? The children begin to see that inhaling appears to remove the part of air which makes things burn. Somehow the body must use it. Perhaps they will also infer that exhaling adds to the air something that does not support burning. For details and illustrations see page 225, *A Sourcebook for Elementary Science.*

Although the amount of oxygen in fresh air remains about the same, the amount in exhaled air is less.

Extending the Concept

Using mathematics. You may wish to combine arithmetic and science by illustrating graphically the chart data (text page 192). Provide each child, or pair of children, with paper ruled into 100 squares (10 x 10). Using one square to represent a quart of air, each child should be able to represent in different colors or shadings the proportions of the components of exhaled air. Children go on to make another graphic model of components of air that is inhaled. The composition of air by volume also offers opportunity for children with interest in numbers to represent the proportions by means of bar or circle graphs.

Making an inference from observations. Breathing, or slow oxidation, uses about one quarter of the oxygen in air (text page 192). Can you predict what part of oxygen might be used in rapid oxidation, as in a burning candle? When we tested the behavior of ordinary air and exhaled air, we saw that the burning candle went out soon after we lowered it into a jar. Can the children predict how much oxygen from the air in the jar the candle uses? (At least one quarter, maybe more.)

Reporting from references. What causes underwater "bends"? Why do some people have trouble breathing at high altitudes? How is it possible for commercial air travelers to fly without oxygen masks at cruising altitudes? These and similar related questions might trigger reading and discussion. Questioning resource persons will enrich the group experience. Children may make reports, or models, and use various forms of visualization. The characteristics and uses of the rare gases in air (e.g., argon, neon, krypton, xenon) offer further opportunity for inquiry. A child interested in chemistry might especially like to report on these gases.

Equipment and Materials

. . . paper ruled in squares

Processes emphasized

Analysis of data
Measurement
Observation
Inference
Library research

Reviewing the Concept

(*Text page 195*)

Before You Go On. A. 1. a 2. b 3. a 4. a 5. b

Using What You Know. 1. The candle in ordinary air will burn longer. This air has more oxygen. 2. Water vapor from exhaled air made the dark spot.

(*Text pages 196–199*)

SUBCONCEPT
Food substances diffuse through membranes.

Section 2: BREAKING DOWN FOOD

Children see that the purpose of eating is to get food to the cells. They become aware of what happens to food in the mouth, stomach, and intestines.

Equipment and Materials

- . . . funnel
- . . . rubber tubing
- . . . container of water
- . . . box of dry cereal
- . . . a paper tissue
- . . . a plastic bag
- . . . rubber bands

Introducing the Concept

Lay a funnel, some rubber tubing, a container of water, a box of dry cereal, a paper tissue, a plastic bag, and some rubber bands in full view of the children. Ask the question: How would you get the cereal through the tube into the plastic bag? With a few hints the children should soon figure out that this can be done by floating the cereal (particles) in water; i.e., mixing them with liquid. If the plastic bag represents the stomach, what do the funnel and tubing represent? Lead into the lesson with these questions:

Why does a dog drool when he sees food? Why do we have saliva?

Digestion begins as food is broken into smaller particles.

Equipment and Materials

- . . . tinder
- . . . wood scraps
- . . . fireproof surface

(See text page 197; also the Teacher's Manual for *Classroom Laboratory 5*.)

Developing the Concept

Smaller pieces, more rapid oxidation. Before or during the reading of the first four paragraphs of the section, let the children see how small pieces of wood burn faster than large ones. (If permissible, use the playground or classroom, employing due safeguards.) Try starting a small fire on a metal tray or other fireproof surface. First, use wooden blocks, as from a construction job scrap pile. Then use smaller scraps and tinder and compare the rates at which fire takes hold. The smaller pieces have greater surface area. How does this suggest the need for chewing our food? (Smaller particles increase the rate at which the foods may be acted on.)

Food substances that do not dissolve must be changed into substances that do.

Soluble, insoluble. The text (page 196) says starch does not dissolve in water. Let the children bring various forms of starch from home to test the statement. Then lead into the investigation on text page 197, following with a discussion of enzymes and digestion under the text heading "Making Large Molecules into Small Ones." An enzyme aids in digestion without itself being permanently changed.

Our digestive organs make our food ready to move through membranes.

Equipment and Materials

- . . . 10 yards clothes rope

The purpose of digestion. Following the text reading, ask for two volunteers to measure off and lay out 20 to 25 feet of clothesline. Imagine the clothesline represents your food tube. How would you arrange it to fit inside a person? Some children may think of coiling the rope to represent the way the small intestine lies in the abdominal cavity. (The length of the small and large intestine together is about 20 to 25 feet.) Why do you think the intestine is so long?

Perhaps we can answer this question if we ask, what does an intestine look like and how does it get food to the cells? Have you seen sausages before they are cooked? What is the skin like? (Thin, like a membrane.) How would your intestine differ? Remember the food has to be churned and pushed along the food tube. This means two layers of muscle cells, one working in one direction and one in another. Intestines are also lined with membrane—much like that which you feel with your tongue inside your mouth. But the intestinal walls have thousands of tiny structures called *villi*, making the wall look somewhat like the rough surface of a bath towel. Dissolved food passes through the villi into the blood where the blood cells take it up and carry it to cells all through the body. Now you can guess why our intestines are so long. The more villi there are, the easier it is for dissolved food to get to the cells.

Processes emphasized

- Measurement
- Analysis of data
- Model making
- Observation
- Reporting

Extending the Concept

What if we had no teeth? Do you know of animals which do not have teeth? Earthworms and birds have an interesting alternative: a gizzard. A freshly opened chicken gizzard or some gizzard stones, preserved in alcohol, are dramatic proof. Some children may recall seeing or hearing of dinosaur gizzard stones worn smooth by the grinding of food in the dinosaur's stomach.

If children mention snakes as animals with no teeth (their teeth are small and for grabbing, not grinding), point out that snakes must digest their meals whole. This is why they are inactive, indeed helpless, for hours until their digestive juices have reduced the "bulge" seen in the body of a snake which has just eaten.

What did you eat today? Which foods did your saliva have to change so they would dissolve? Encourage the children to create a display or poster for the bulletin board and to demonstrate simple tests for starches, proteins, fats, and sugars (see Section 9, Unit Four).

(*Text page 199*)

Reviewing the Concept

Before You Go On. A. **1.** b **2.** b **3.** a **4.** a **5.** a

Using What You Know. **1.** Chew your food into small pieces. Then the enzymes in the digestive tube can act on your food more easily. **2.** In the stomach and small intestine.

(*Text pages 200–206*)

SUBCONCEPT

The cell is the unit of structure and function.

Section 3: SOME IMPORTANT CELLS AND THEIR WORK

Children's understanding of how one cell functions leads to insight and appreciation for special functions of different types of cells.

Processes emphasized

- Analysis of data
- Uses of tools
- Observation
- Inference
- Hypothesizing

Introducing the Concept

Since the concept is concerned with (a) cell structure and (b) cell function, it may be desirable to review, so far as is needful, the parts that are common to a living cell. Take an inventory of the children's concepts and misconceptions by initiating a review of onion skin cells and cheek lining cells discussed in Unit Four, pages 153–160. What do these cells have in common? Encourage children to make chalkboard review drawings, labeling cell membrane, cytoplasm, and nucleus. Be sure children recall that the cell is the smallest living unit of an organism just as atoms and molecules are building blocks of all matter.

Lead into development of cell function by asking:

Are all the cells in your body alike?

Developing the Concept

Children begin to see the unity (the basic structure) in all cells and the diversity in terms of adaptation to function.

Likenesses and differences in cell structure. This is a good opportunity to use the illustrations of different cells on text pages 201–04 for a "picture reading" lesson. As children examine each illustration of covering cells, muscle cells, supporting (bone, cartilage, ligament) cells, nerve cells, and red and white blood cells, ask them to locate the three basic parts of the cell structure. (These cells are identified by a symbol in the child's text and next to the illustration.) What are the differences?

Covering cells have adjacent boundaries.
Muscle cells are long and thin, like strings or fibers.
Supporting cells are packed close together with spaces between.
Nerve cells have antennae, fibers from the center of the cell.
Red blood cells are like round flattened disks.
White blood cells are of differing irregular shapes.

Children with home microscopes or access to references illustrating types of body cells might wish to trace drawings of these and other cells of the body for general use by the class.

Cells with different functions appear different in detail, but not in basic structures.

Relating cell structure to function. You may now wish to ask the question: Why do you think the cells look so different? Depending on your class, you may wish to elicit responses before children read the text or you may wish to have them read before answering. With either procedure, you will expect to arrive at these end results:

Covering cells: adjacent boundaries keep out bacteria and other particles; they fit together to form a covering sheet.
Muscle cells: Their fibrous shape enables them to expand and contract.
Supporting cells: Their closeness gives rigidity, and the spaces enable them to be nourished by other cell types.
Nerve cells: The fibers are like radio sending and receiving antennae to pass along messages from one part of the body to another.
Red blood cells: Their shape gives them a large surface to pick up food and oxygen, and these are all carried easily in the blood.
White blood cells: They can move by themselves and "flow around" bacteria or other foreign matter in the blood, thus making it harmless.

Cells secrete nonliving material.

The body's nonliving parts. Are all parts of the body built of living cells? (No.) Which parts are not? (Hair, nails, bone, tooth enamel.) Children may mention teeth, rather than the enamel. This may be an opportunity to have them identify the parts of the teeth in a model or diagram loaned by the school nurse or dental hygienist. Is the pulp living or nonliving? (Living; it contains blood vessels and a nerve.) Where do the nonliving parts in the body come from? (They are made by the cells.) Some cells, therefore, make substances that are useful to the body in covering it (hair), giving it a strong supporting structure (bone), and protecting it (tooth enamel).

Similar cells with similar functions are organized into tissues.

Equipment and Materials

. . . thread
. . . cord

How cells work together. In order to conclude the section and afford a bridge to the next, pass out lengths of light-weight sewing thread and twine, such as parcel-post wrapping cord. Let the children pull on each end. Why does the thread snap? The clue lies in an examination of the thread and the twisted strands in the cord. The cord is a number of threads organized to give strength. How are tissues of cells like the cord? (They are similar cells organized for a special function.)

Extending the Concept

Building science vocabulary. What new words did you find in the section?—(e.g., *pulp, cartilage, tendon, ligament.*) How would you explain them without using words? For example, is your nose all cartilage? All bone? Neither? Feel it and decide. What would you use as a model?

A word such as *cilia,* which the children encountered in studying paramecia in Section 6 of Unit Four (page 169), now appears in a new context. The word might be illustrated by drawings and diagrams. Imagine a boat propelled in the same manner as are paramecia, as if by tiny oars. Imagine the cells in the lining of the tubes leading to the lungs as boats that are anchored. What is the difference in the work of these tiny oars? (Cilia *move* the paramecia, but in the bronchial tubes they move bacteria and other matter *away* from the cells.)

Using a microscope. Wherever possible, widen children's horizons by encouraging exploration of the vast world to be seen through a microscope. Microscopic, prepared cross-sections of bone and other cells for study may possibly be secured on loan from the high school biology teacher. Some children may be interested and able to prepare slides from muscle and other cell tissues secured from a butcher.

Keeping cells healthy. Do you know the difference between ligaments and tendons? Do you know the difference between neurons and neutrons? (Some children may indulge in carelessness and over-confidence!)

(Text page 206)

Reviewing the Concept

Before You Go On. 1–2. **A.** Bone cell supplies support. **B.** Skin cell fits with other skin cells to cover outside and line inside of body and body organs. **C.** Muscle cell expands and contracts to provide movement. **D.** Red blood cell carries oxygen to other cells and carries away carbon dioxide.

Using What You Know. 1–2. **A.** Cell from nerve tissue; it passes messages from one part of the body to another. **B.** White cell from blood tissue; it aids in destroying bacteria that may get into the blood.

(*Text pages 206–220*)

SUBCONCEPT

In many-celled organisms, groups of cells and tissues are organized into organ systems, all specialized to perform the body's functions.

Section 4: WITHIN THE BODY

Children gain further insights and understandings of that amazing aggregate of cells, the human body.

Note. This section is very long, but it is purposely not separated into smaller divisions, so that the children will gain a total understanding of their bodies—from molecules to cells to tissues to organs to organ systems to complete organism. You may wish to break up the section into four or more daily "bite-sized" lessons by studying two or more organ systems in one day. This involves assigned or cooperative reading of the text (do not forget "reading" of the illustrations) and discussion supplemented by suggestions that follow. The suggestions are indicated by letter to correspond to the divisions of the textbook section.

Equipment and Materials

. . . photographs of invertebrates

Introducing the Concept

Display pictures of animals such as earthworms, insects, jellyfish, or other invertebrates. Initiate discussion with the question: What can you do that these animals cannot do? After a listing of ten or a dozen ideas, continue with a short discussion of these questions, which lead into the concept of the lesson:

What body parts (structures) enable you to do so many different things? How do these body parts work (function) separately and together?

Children begin to visualize the body as more than a mass of cells—rather, as an organized structure.

Processes emphasized

Observation
Recording
Model making
Inference
Hypothesizing
Theorizing
Investigation (demonstration
and model making)

Developing the Concept

The organization of the body. Although analogies are never exact, it may help to suggest that children compare their body to a building. Your school, for example, is organized to carry on many kinds of activities during the day. The people in it carry on these activities. What is the framework of the building? Yours? (Skeleton.) What part of the building handles the food system? (Lunch room.) What system in your body supplies food to the cells? In a word, into what kinds of systems are your body cells, tissues, and organs *organ*ized?

It would be well to encourage children to keep a record of the new science terms they find in this section. The density of terms is greater than in any other section in the book. Suggest children make two columns for their vocabulary record, with a new heading across these columns for each system as they study it. In the first column (STRUCTURE WORDS), children place any word that helps them answer the question: What is our body really like? In the second column (FUNCTIONS), they answer the question: How does the structure help us explain how the body works?

The organs of the digestive system work together.

A. *The digestive system.* What organs help you make a sandwich ready for your cells? As each organ is cited, children identify it in the illustration on text page 207. If you have wall charts of the human body, children will be fascinated in pointing out the location of the organs. Elicit that each organ has its special job to do in preparing food for the cells. Children will recall from Section 3 that cells make up tissues and tissues make up organs.

The organs of the respiratory system are so structured that they provide the body cells with a continuous supply of oxygen.

Equipment and Materials

. . . bell jar
. . . glass tubing
. . . rubber sheeting
(as illustrated in the child's text, page 208.)

B. *The breathing (respiratory) system.* It is not difficult to put together the working model of the breathing system described and illustrated on text pages 208–209. Two or three children may prepare it in advance under your direction and demonstrate it. Others may also try it out. The relationship to be developed is *not* that lowering the body's diaphragm sucks in air, but that greater pressure outside the lungs causes air to rush in through the nostrils. An opportunity to relate the concept of pressure (developed in Unit One in relation to mountain building) to a body function is offered. In fact, children should be able to note application of earlier concepts studied, such as the passage of substances through a membrane (air through cell membranes) and oxidation of substances within cells. What system changes the air in a building? (Ventilation.) What system filters out dust and pollen? (Air conditioning.)

The circulatory system works with the digestive and respiratory systems to provide the cells with substances they need.

C. and D. *The circulatory system.* These two divisions could well constitute one lesson. There is no cell in the body that blood does not reach. Why must this be so? (Each cell must have food and oxygen and rid itself of carbon dioxide and other wastes of oxidation.) Close reading of the text is recommended. Encourage the children to use the illustrations in the text, or on wall charts, to trace the flow of blood through the body. Encourage them also to point out other concepts they have studied. (Dissolving of substances, oxidation, passage of substances through a membrane.) What system in a building does the body's circulatory system resemble? (Heating system with its valves and any pumps or motors that help circulate the heat.)

The skeletal and muscular systems provide the body support and protection and enable it to move about.

Equipment and Materials

. . . paper skeleton
. . . photographs of invertebrates and vertebrates

E. and F. *The muscular and skeletal systems.* Again it is well to consider these two systems together. Hang up a paper skeleton such as you find in dime and toy stores at Halloween. What if we had no skeleton? (No support.) What if we had no muscles? (No motion.) Display the pictures of the earthworm and jellyfish with which you started the section, adding pictures of vertebrates; for example, a bird, a fish, and a horse. Why can't the earthworm and jellyfish perch on a branch like a bird, dart through water like a fish, run and jump on four legs like a horse, walk and stand on two legs as you do? Children begin to see that muscles and bones must work together to provide support and motion, and that animals with skeletons can do many more things than those without. (Of course, earthworms have muscles—if a child should ask.) Let the children now read divisions E and F, noting the kinds of muscles and the different kinds of motion that are possible because of the way the bones of the skeleton fit together. Be sure also that they see how important the skeleton is in protecting organs inside the body, such as the heart and brain.

How do muscles work? The child's text says: "Muscles exert a force when they contract." Do muscles always have to be attached to bones?

(No.) Where have we met other organs that contract? (Stomach, intestine, heart.) These organs indeed do work as the muscles in them relax and contract.

What is a better analogy than a building for the muscular and skeletal system? (A construction crane or steam shovel. As the cables are shortened, an arm on the machine moves as if on a hinge, or parts of the machine can be turned on a pivot.)

The nervous system serves to coordinate the systems of the body.

G. *The nervous system.* How do we know what is going on around us and, when we have a pain, inside us? What kind of system tells us? What are some of the organs of this system? Children verify their responses by reading text page 218. What system in a building is like the nervous system in the body? (The communications system of telephones and bells; the wires carry messages from one part of the building through the central switchboard to another part. Connections are made between incoming wires and outgoing wires.) What are the incoming "wires" in the nervous system? The outgoing "wires"?

The excretory system enables the other systems to maintain a balance by removing undesirable wastes of cell oxidation.

H. *The excretory system.* Why must cells get rid of wastes? Review with the children the earlier concept of oxidation of food substances during which carbon and oxygen combine to form carbon dioxide. Do animal cells use carbon dioxide? (No.) What other substances are harmful to cells if they have too much for them? (Too much water and certain salts like urea.) What system in a building does the body's excretory system resemble? (Waste and garbage disposal system.)

The organ systems work together in performing the body's functions.

Keeping the organ systems working smoothly. To conclude the section, you may wish to explore with the children the advantages of good hygienic practices, such as regular bathing, in relation to the concept that all cells are organized to work as a team in performance of the body's functions. Local resource persons such as the school nurse or doctor may be invited to discuss questions with the class in a summarizing session. Suggest that these persons, in order to neutralize children's often unfounded fears of a routine physical examination, relate the medical check-up with the functioning of the body systems just studied.

Extending the Concept

Equipment and Materials

. . . watch with second hand
. . . record player
. . . musical record

Exercise and pulse rate. Suggest that children work in groups of two. Let them take turns doing the following: Take pulse rate at rest. Now do mild exercise to a musical record for two minutes. Check pulse again. Why the change? (Cells are doing more work and require more oxygen for release of energy from food.) Now repeat with vigorous exercises for two minutes. Note how rapidly the pulse returns to the "normal" pulse rate, which was checked at the beginning of the investigation. Why? (The oxygen need has been satisfied.)

Equipment and Materials

. . . 2 yardsticks

A model of heart-valve action. How do heart valves work? Arrange chairs or desks to represent the two auricles and two ventricles of the heart, leaving an entrance for "artery" and an exit for "vein." Divide the auricles from the ventricles with yardsticks as "valves." Two children operate the valves. Other children enter from the artery and move forward as the "valves" are opened and closed. With a little practice, the two operators can simulate heart action by synchronizing the opening and closing of valves. All the children may enter, leave, and return to the heart in the sequences described in the text (pages 212–214) to dramatize body circulation.

A group demonstration. If the class is accustomed to committee work and there is enough reference material at hand, it might be useful to set up committees to investigate several of the organ systems described. Or it may work better for you to move the entire class toward a consideration of one or more systems in more detail than developed in the textbook. Take the circulatory system, for example.

Equipment and Materials

. . . pint jar
. . . gallon container
. . . red ink or dye

Blood, like all other body parts, is made up of cells. Many children will have heard of blood donors and blood banks. Children may illustrate the small fraction of blood withdrawn from the total blood supply of donors by measuring out 12 to 16 pints of water tinged with red ink or vegetable dye for realism. Withdraw one pint from the container and compare volumes. What happens in the donor's body? Children investigate and report how new blood cells and plasma are made.

Do you know why you apply Mercurochrome or other antiseptics to a cut? Role-playing to illustrate good first aid for cuts might enliven and clarify meaning.

From your present knowledge of cells, why does a clean cut heal faster than a jagged tear or puncture wound? (Better contact between the cells at the cut edges.) Why are doctors concerned about deep puncture wounds? (Infection by bacteria.)

Health texts are useful resources, but using school health personnel, such as your school nurse or doctor, if available, is one of the most effective ways to encourage care of the body and its cells. Should you be fortunate enough to be teaching children having parents with medical training, your class will be deeply interested and enriched by any contributions you can encourage these parents to make.

(Text pages 219–220)

Reviewing the Concept

Before You Go On. 1–2. Brain and spinal cord (centers of the nervous system); lungs (interchange oxygen and carbon dioxide); heart (pumps blood through the body); stomach (starts breakdown of proteins in digestion); liver (provides a digestive juice for the small intestine); small intestine (finishes the work of digestion and passes digested food to the blood stream by diffusion); large intestine (excretes wastes of digestion).

Using What You Know. 1–2. (*Left to right*) heart (circulates the blood); lungs (exchanges oxygen from the air and carbon dioxide from oxidation in the cells); stomach (an organ in digestion of food).

(*Text pages 220–225*)

CONCEPTUAL SCHEME

A living thing is the product of its heredity and environment.

UNIT CONCEPT

The cell is the unit of structure and function; a living thing develops from a single cell.

What are some differences between living and nonliving substances?

Section 5: THE MAIN CONCEPT: THE BODY

Children review the subconcepts and supporting activities of the unit, clarifying their understanding of the body as an organism—a collection of interdependent cells, tissues, and organs, each working together for *living*. The concept of living things as matter organized in structure for life activities is reinforced and extended to adaptation to life in an environment.

CONCEPT SUMMARY

Living and nonliving things. In plain view of the children, place a box of sugar or a sugar bowl, a living plant, a rock, a brick, and a piece of wood.

Which of these are living? Nonliving? How do you know? How could you prove it?

Now produce labels reading ORGANIC, INORGANIC, ORGANIZED FOR LIVING, NOT ORGANIZED FOR LIVING. You may need to explain the first two terms: *Organic*—produced by living organisms; *inorganic*—not produced by living organisms. How are all these terms related? (*Organ* is part of the word.) Ask for volunteers to arrange these labels correctly with respect to the five objects above.

Now ask the children to verify and, as needed, correct these decisions from the text reading. When children finish, they can begin listing things living and nonliving: (a) in our classroom; (b) to be seen from the window. How do you relate what you have read to carving or mutilating a tree? To a bird that a cat has crippled?

When is a plant not a plant?

A school-ground study trip. If possible and seasonable, take the class on a ten-minute trip around the school grounds. Ask the children to show you a plant. Pick a leaf and ask, is this a plant? Why not? Pick a weed, breaking it off just above ground. Is this a plant? Why not? Pull a weed or bunch of grass, roots and all. Why is this not a plant? It will die, removed from soil, moisture, and nutrients. Contrast with a potted plant.

If the study trip is not possible, display the same plant parts in the classroom. Brief study trips as suggested have many values beyond the immediate enrichment in science. You may find it useful to investigate proven methods of utilizing the school grounds as a science laboratory.

How are organisms adapted to their environment?

Adaption, ecology, and life zones. You have seen how your body structure has adapted you to living in your environment. Which environments could you not live in; at least, not without special equipment? (Air, water.) This offers an opportunity to review man's special structures and adaptations. Children now need to see that each living thing, as a total organism, is adapted to live in its own special kind of environment.

What animals can live in water or air? If the classroom has an aquarium, a goldfish is a good starter for observation of how animals are adapted to special environments. Ask the children to suggest the life functions of a fish. How is it adapted by structure to carry on these functions in the water? Suggest similar consideration of other animal forms, e.g., cats, chickens, insects, etc. Children may study them firsthand and report.

If time permits, move children toward the concept of plant and animal relationships (ecology). For example, in what ways do animals and plants depend on the tree on the school playground? (It harbors birds, insects—perhaps mammals—and usually other plants, such as lichens, mosses, and fungi.) All these living together are called a *community*. An ecologist usually speaks of larger communities such as the forest, the meadow, or the pond. Encourage children to suggest communities in miniature and list the plants and animals living together.

You may wish to display pictures of tropical regions and deserts, of forest and meadow, of valley and mountain top that clearly show differences in the kinds of plants and animals found there. The amount of moisture and the mean annual temperatures are thought to be factors in the distribution of living things in these life zones. How is a palm tree adapted for life in a warm region but not in a cold one? How is a cactus adapted to hot, dry regions? Children may suggest adaptations of animals to these different areas. Children interested in birds (do they have home bird-feeders?) may report on the kinds of birds that nest on the ground, in shrubs, and in trees. Their distribution is, in fact, controlled by their food supply.

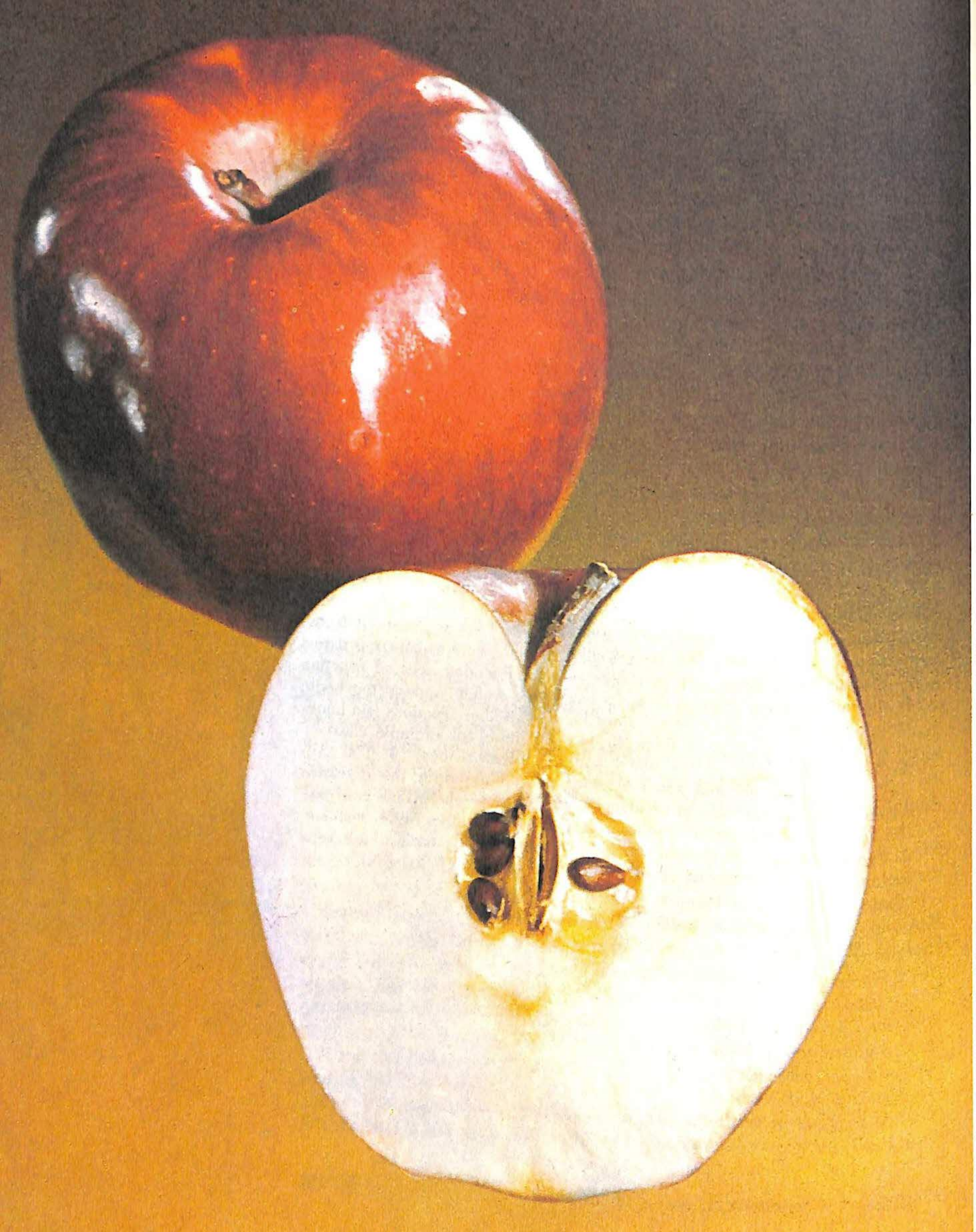
(*Text pages 222–225*)

FIXING THE MAIN CONCEPTS

A. **1.** Muscle cell. *Muscle cells* make up muscle tissue which functions in the movements of the body. Skin and cheek cells both serve as covering tissue. **2.** Bone cells, ligament cells, cartilage cells, and tendon cells all function as supporting tissue. Bone cells make hard bone which supports the body. Strong, fiber-like ligament cells join one bone to another. Tendons join bones to muscles. Cartilage gives shape to ears and nose, for example. Two of the other cells make up the blood and two other tissues. **3.** The salivary gland, stomach, and small intestine are all found in the digestive system. They all function in breaking food into molecules which can pass through cell membranes. The other organs are in five other organ systems. **4.** Leg to right auricle to right ventricle to lungs to left auricle to left ventricle to leg. (The *same* red blood cell may not return to left leg but to another part of the body.)

B. Child's answers. Refer to textbook glossary, page 359.

C. **1.** d **2.** d **3.** c **4.** a



UNIT FIVE

BUILDING BLOCKS OF THE BODY

Let's suppose that you ate an apple yesterday. Now wiggle your finger. How does the energy in an apple get to your finger so that the finger can wiggle? Some of the molecules of that apple must have made their way into your wiggling finger. What path did they follow?

Here is another puzzle. Close one hand into a fist. Open it. Why did you close and open your hand? Because you were requested to do so, of course. You read the request with your eyes. Then your hand moved. But how did the request reach your hand?

You can see that you are not only made up of cells, but that the cells somehow work together. How your cells do this is the story of this unit. To start the story, take a deep breath, and let it out. Turn the page.

1. A Deep Breath

By the time you have finished reading this sentence, every person on Earth will have taken a breath of air.

We all have to breathe. What are we doing when we breathe? We are taking in molecules from the environment, molecules to be used as building blocks. More than that, we are giving out molecules as well. When we breathe in, or *inhale,* molecules are taken in. When we breathe out, or *exhale,* we return molecules to the environment. But the air we exhale is not just the same as the air we inhale.

Why is this so? Let's see what happens when we breathe.

The Part of Air We Use

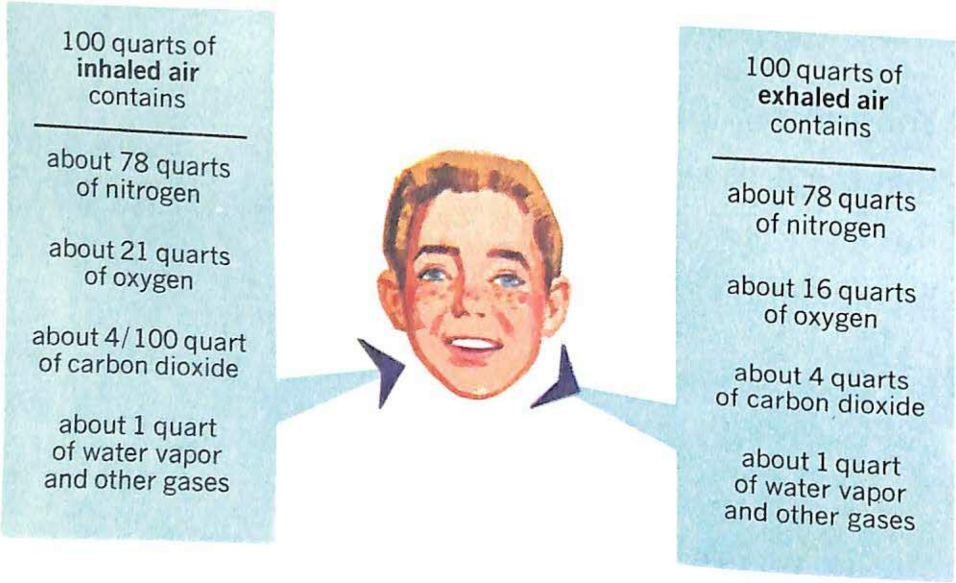
We inhale and exhale air. What do we do with this air when we have it in our bodies? Here is some evidence. See the drawing marked with a square. ■ More than a thousand people were examined to get this evidence.

Let us compare the inhaled air and the exhaled air. The inhaled air contained about 78 quarts of nitrogen gas. So did the exhaled air. Nothing happened to the nitrogen, it seems.

Now look at the oxygen inhaled and exhaled. The air inhaled contained about 21 quarts of oxygen. The air exhaled, however, held only 16 quarts of oxygen. About 5 quarts of oxygen were taken from the air in breathing. About one quarter of the oxygen in the air was somehow used up. The evidence is that oxygen is used up during breathing.

With carbon dioxide, the opposite happens. There is very little carbon dioxide in the air we breathe. So very little carbon dioxide was inhaled, about $\frac{4}{100}$ of a quart. Yet the exhaled air contained about 4 quarts of carbon

■



100 quarts of **inhaled air** contains

about 78 quarts of nitrogen

about 21 quarts of oxygen

about 4/100 quart of carbon dioxide

about 1 quart of water vapor and other gases

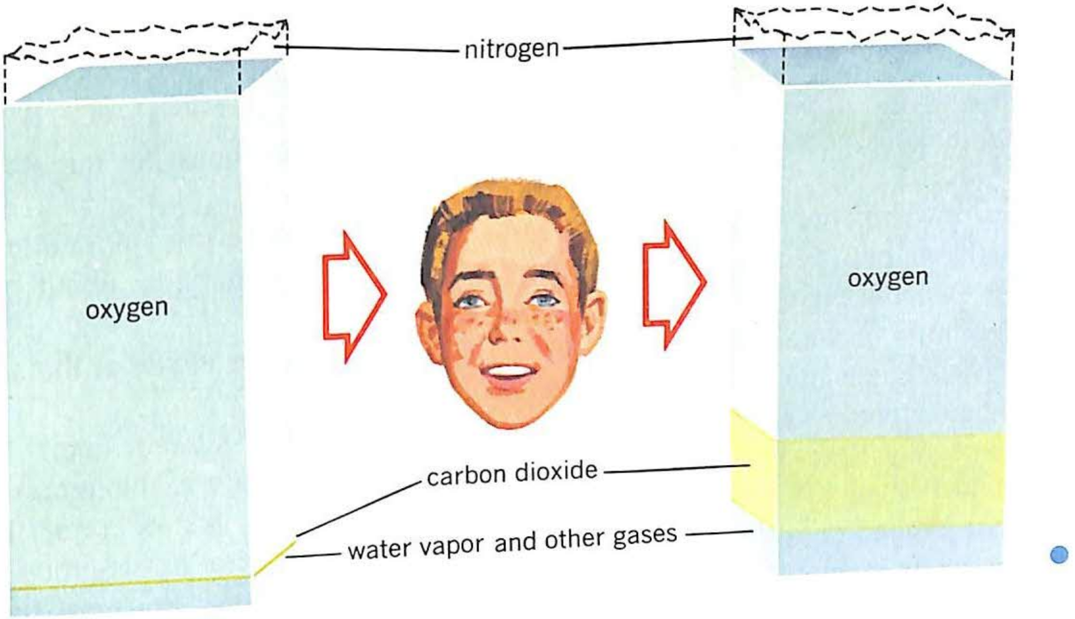
100 quarts of **exhaled air** contains

about 78 quarts of nitrogen

about 16 quarts of oxygen

about 4 quarts of carbon dioxide

about 1 quart of water vapor and other gases



dioxide gas. The evidence is that carbon dioxide is produced during breathing. About one hundred times more carbon dioxide is exhaled than is inhaled.

At this rate the oxygen would soon be used up. Carbon dioxide would fill the air and we would all die. This does not happen, however. At the same time that you are exhaling carbon dioxide, green plants are using it and are, in turn, giving off oxygen gas. In this way, the carbon dioxide and oxygen in the air remains about the same. We keep exchanging molecules with the plants.

What part of the air we breathe do we use? It is clear that we take oxygen from the air as we breathe. ● Of course this fact fits in with something else we know, that our cells use oxygen. Our cells combine oxygen with food substances. The oxygen that our body cells use in their work is taken from the air we breathe.

The other substances that our body cells need are obtained from the food we eat. How do the molecules in a piece of meat or an apple get into our cells? We shall look into this next.

The rate at which people inhale and exhale has been studied by scientists. They have found that most boys and girls your age inhale (and exhale) about sixteen to eighteen times a minute. Some inhale more slowly, from twelve to fifteen times in a minute. Some inhale as often as twenty times in a minute. Most adults inhale about fifteen times in a minute. How many times do you inhale in a minute? Do your classmates inhale at the same rate? See for yourself. Try the investigation on the next page.

AN INVESTIGATION into Rate of Breathing

Needed: a clock or watch

Do this investigation with your classmates. Have one person act as timekeeper, to signal the beginning and end of one minute of time. During this minute *silently* count the number of times you inhale. Inhale and exhale just as you do usually. Enter in a table like the one shown below the number of times that you inhaled during the minute.

Now compare your rate of breathing with your classmates. Fill in your table by asking those who found that they inhaled eleven or fewer times per minute to hold up hands. Write in the number. Then observe how many breathed twelve to fifteen times per minute . . . and so forth.

Now you can use this information to answer these questions about your class.

1. Does everyone inhale at the same rate?
2. What is the slowest rate? How many pupils are in this group?
3. What is the fastest rate? How many pupils are in this group?
4. Which group has the most pupils in it?

Additional Investigation: Predict what your breathing rate will be after a little exercise. Test the prediction.

Times I Inhaled in One Minute ______

Times Inhaled in One Minute	*Number of Pupils*
11 times or fewer	______
12 to 15 times	______
16 to 18 times	______
19 to 21 times	______
22 times or more	______

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. When we breathe in, we
a. inhale b. exhale

2. People inhale and exhale at
a. the same rate b. different rates

3. The amount of nitrogen we inhale and the amount we exhale are
a. about the same b. very different

4. The amount of oxygen we inhale, compared with the amount we exhale, is
a. larger b. smaller

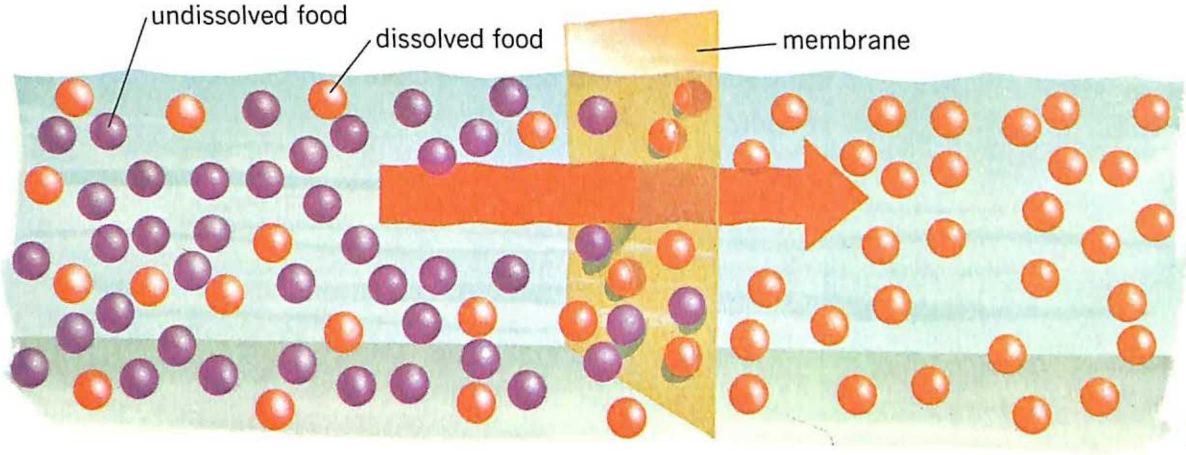
5. The amount of carbon dioxide we inhale, compared with the amount we exhale, is
a. larger b. smaller

B. Write a paragraph or two in answer to this question: "What Happens to the Air We Inhale?"

USING WHAT YOU KNOW

1. A candle is placed inside a jar of fresh air. Another candle is placed in a jar of exhaled air. Do you think both candles will burn for the same length of time? What is the reason for your answer?

2. A boy went to the chalkboard and breathed on it. A dark spot appeared on the board. It soon disappeared. What was the dark spot? What made it?



2. Breaking Down Food

It is hard to believe that an apple, or a piece of chicken, or a jelly sandwich, can get into our body cells. Yet we know that the elements and compounds in what we eat do get to all our cells. We know, too, that to get into a cell the elements and compounds must pass through a membrane. Let's see how this happens.

Which burns faster in a furnace, large pieces of coal or small pieces? Small pieces burn faster, of course. Oxygen can get at small pieces quickly and combine with them. Which then would be acted on faster, large pieces of food or small pieces? Small pieces, certainly. Our food is, in fact, broken down into small pieces. The part of the body that first breaks down food is the teeth.

Still, it is not enough to have the food in small pieces. The elements and compounds in food must pass through membranes to get into the cells. The only compounds that can pass through membranes are compounds that dissolve in water. *The food substances must be changed into compounds that dissolve in water.*

Let's take an example. Starch is a food substance. It does not dissolve in water. In the body, however, starch is changed into compounds that do dissolve. How is starch changed? See for yourself in the investigation on the opposite page.

Making Large Molecules into Small Ones

Saliva is the liquid you find in your mouth when you think of a good meal. It is the liquid that moistens your food as you eat.

Saliva changes starch. It changes starch into compounds that dissolve in water and can pass through membranes. When you take a bite of a sandwich, your teeth chew the food into small pieces. The saliva in your mouth can get at these pieces easily.

AN INVESTIGATION into How Starch Is Changed

Needed: starch, warm water, Benedict's solution, two test tubes, a glass, a beaker, two labels, a teaspoon

Stir a level teaspoonful of starch into a glass of warm water. It will make a cloudy mixture, since starch does not dissolve in water.

Label one test tube number **1,** the other number **2.** Pour in the mixture so that each tube is half full. ■

To test tube 1 add about a teaspoonful of saliva from your mouth. To test tube 2 add about a teaspoonful of warm water. Shake the test tubes. Put both test tubes in a beaker of warm water.

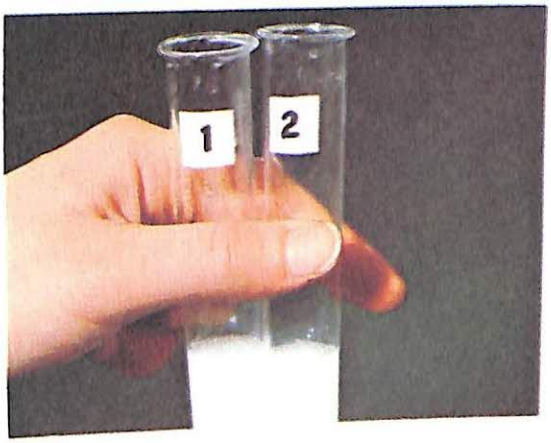
After about 10 minutes add a teaspoonful of Benedict's solution to each test tube. ● Heat the test tubes in the beaker of water. Observe what happens as the water boils. Here are the results of one test. ▲

Benedict's solution changes color when sugar is present. According to this evidence, does test tube 1, with saliva, contain sugar?

Does test tube 2 contain sugar?

What does this suggest about saliva?

Additional Investigation: Put the same amounts of starch mixture and saliva in test tubes. Put one tube in a refrigerator. Put the other in a glass of warm water. After 10 minutes test both tubes with Benedict's solution. What do you find?



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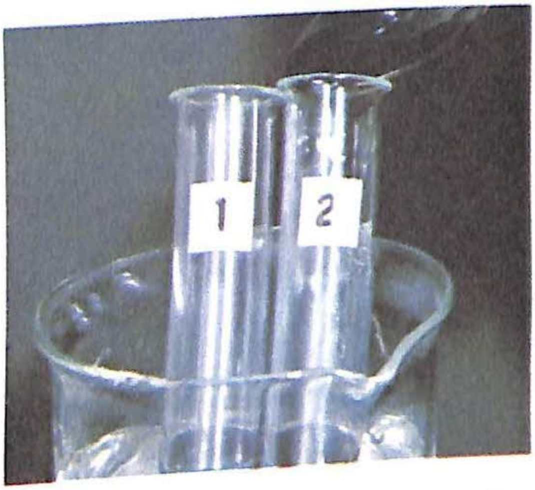

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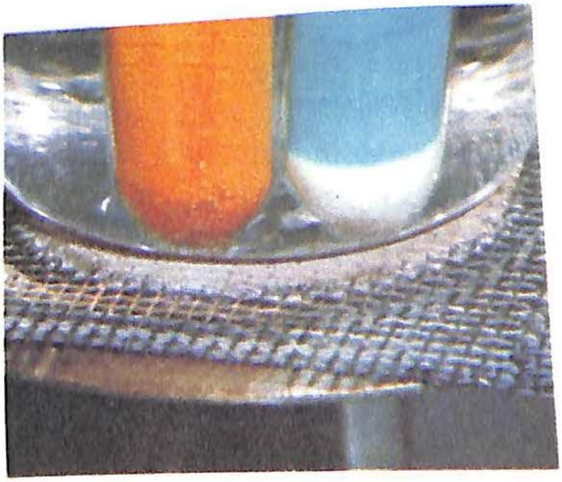

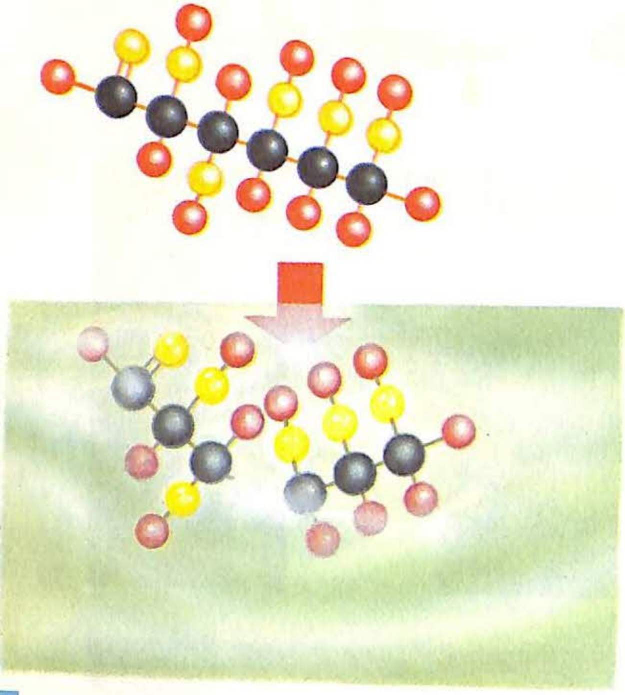

The saliva begins to break down some of the sandwich—mainly the starch.

What does saliva do to starch? It changes starch into a sugar called malt sugar. The dissolved sugar can pass through a membrane.

Saliva is largely water, but there is a substance in saliva that breaks down starch. This substance is called an **enzyme** (en′zīm). It is the enzyme in saliva that breaks down starch into sugar. It breaks down some of the large food molecules into small molecules that can pass through membranes.

Of course we eat other food substances besides starch. We eat meat, butter, milk, fruit, and so forth. Most of the foods we eat contain carbohydrates, proteins, and fats. They are the kinds of food materials that provide the molecules the body needs. In other words, we eat carbohydrates and proteins and fats. Most of these must be broken down into molecules that can pass through membranes. Other enzymes do these jobs.

When food is broken down by enzymes, we call the process **digestion** (di·jes′chən). Digestion means breaking down food compounds that do not dissolve into compounds that do dissolve. Mostly it means breaking down very large molecules into smaller ones. Where does digestion take place? In your mouth, stomach, and intestines. It is taking place now. Enzymes are at work in your stomach and intestine. They are breaking down large molecules of the food you have eaten into smaller ones.

Only digested food can pass through the membranes of cells. But once inside a cell, the food is broken down *again*. A sugar molecule inside the cell, for instance, is broken down into smaller parts. ■ When a sugar molecule is broken down in this way, it yields energy to the cell. The cell uses this energy in the ATP energy cycle for growing, and for its other activities.

When you stop to think of it, this is the real purpose of eating: to get food to your cells. The cells do the rest. They exchange molecules with their environment. They change some of the food you eat to make more of you.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Before food is used by the cells in our bodies, it must be
a. cooled
b. broken down

2. To break down food substances in the mouth, stomach, and intestine, the body uses
a. oxygen
b. enzymes

3. When large molecules of food are broken down in the intestine, we say the food is
a. digested
b. dissolved

4. The molecules that have been broken down can then
a. pass through membranes
b. digest enzymes

5. One example of digestion is the breaking down of
a. starch into sugar
b. sugar into starch

B. Write a paragraph or two on this topic: "What Happens to Food in the Mouth, Stomach, and Intestines?"

USING WHAT YOU KNOW

1. If a boy gulps his food in large chunks, what advice would you give him? What reasons would you give him for your advice?

2. Experiments have shown that proteins and fats are not digested in the mouth. Where are they digested?

ON YOUR OWN

You know what one enzyme in saliva does. In the library, find out what the following enzymes do in your body: pepsin (pep′sin), in the stomach; trypsin (trip′sin), in the intestine.

3. Some Important Cells and Their Work

You are alive—a most important fact, to be sure. You are alive because your cells are alive. However, some parts of your body are not made up of cells. Does it surprise you that some parts of your body are not alive?

Think of the last time you had a haircut. As your hair was cut you felt no pain. Hair is not alive. It does not take in oxygen or food substances. The cells around the *root* of a hair are alive, and grow. This is what makes the hair get longer. But the hair itself is not alive. Notice that the cell structure of a hair cannot be seen through a microscope. ■

Are there other parts of the body that can be cut without pain? The nails, of course. They are not alive.

When you are at the dentist's it seems as if your teeth were very much alive! Yet it does not seem so when you brush your teeth, does it?

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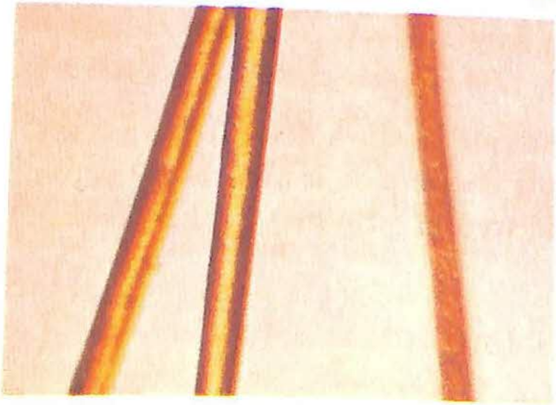

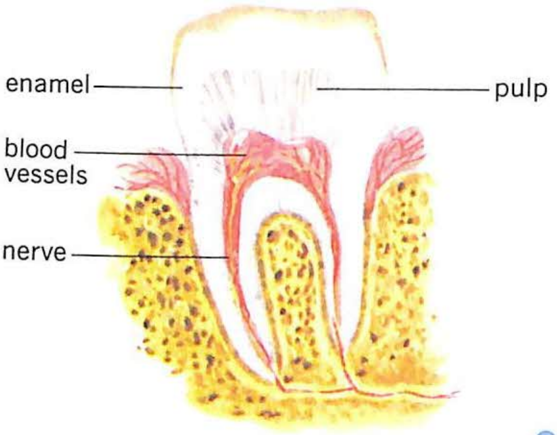

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The living cells in your teeth are not exposed. They are well protected. Your gums are lined with living cells, but each tooth is covered with a hard material that is not alive. It is called enamel. Inside each tooth, however, is the pulp, which contains blood vessels and a nerve. ● The pulp is very much alive.

Where do these nonliving parts such as enamel and nails and hair come from? They are all made by living cells. There is another hard material in your body, made by cells, that is important to you. Bone is made by cells. Much of the bone in your body is not alive. Right now your cells are making more bone. This is one reason why you are growing taller.

There are many different kinds of cells in your body, doing many different jobs. The cells that make bone, for instance, differ from the cells in a muscle. The cells in your brain differ from the cells at work in your blood. However, scientists have managed to classify or group cells, just as they have classified many things. Matter is classified into solids, liquids, and gases. Animals are classified into many different groups by scientists. The cells in your body are also classified by the kind of work they do.

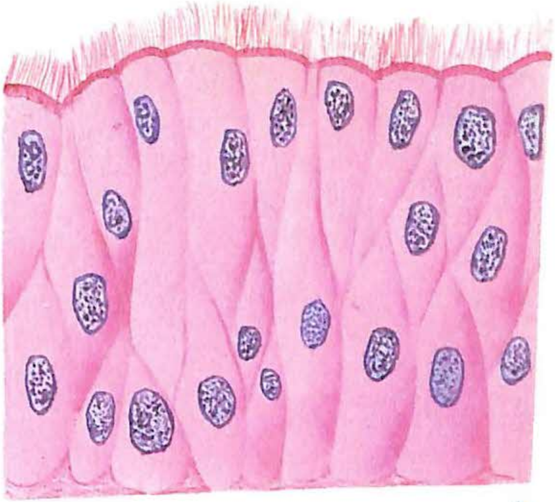
Let's look at some of these different groups of cells in your body, and the jobs that they do.

Cells That Cover

A sheet of cells covers you from head to foot. These **covering cells** are skin cells, shown on page 164.

So long as the covering cells of the skin are unbroken, **bacteria** cannot get into the body through the skin. Bacteria are tiny organisms that may cause illness. When the skin is broken, more skin cells grow to knit covering cells together again. Thus the opening made in the sheet of covering cells is closed.

There are covering cells on the *inside* of your body also. For example, the inside of the stomach and intestine is covered with cells. The inside of the tubes leading to the lungs is covered with cells like these.▲ The tiny hairs on these cells are called **cilia.** Bacteria catch on these hairs. Movement of the hairs waves the bacteria out of the lungs, to where a sneeze or a cough may get rid of them. Why should a handkerchief be used when you sneeze or cough?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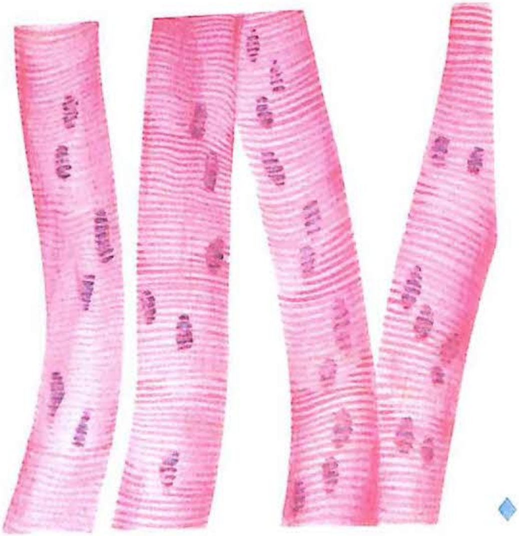
Cells That Move Your Body

Move your fingers, bend your arm, turn your head. **Muscle cells** are at work. There are many different muscles in the body, over eight hundred of them, in fact. Each muscle is made up of many cells which work together. However, there are only three kinds of muscle cells.

Here is one kind of muscle cell.◆ When you lift a finger or move an arm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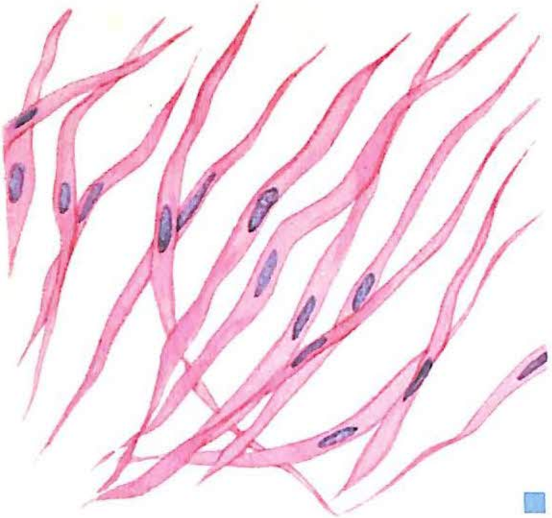

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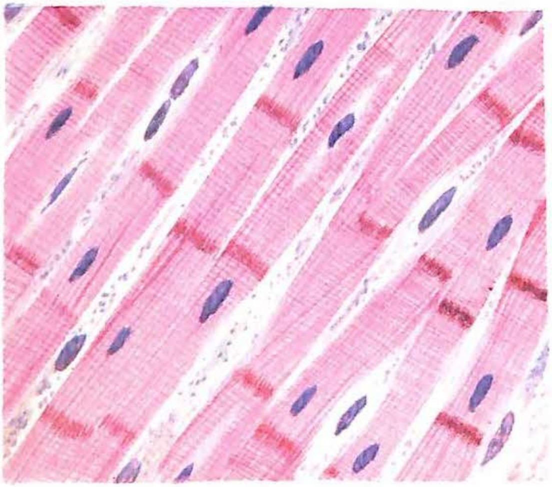
or leg, this kind of muscle cell is in action. The muscles made up of these cells do what you command them to do. In other words, muscle cells of this kind are *under your control.*

Here is a second kind of muscle cell. ■ This kind is *not under your control.* Can you cause the muscle cells of your intestine to digest your food or to stop digesting it? No. These muscle cells work without your commanding them.

●



The muscles of your heart are not under your control either. Your heart beats without your thinking about it. But as you can see, these heart muscle cells and the muscle cells of the intestine look different. ● They do different kinds of work. The heart muscles are made up of the third kind of muscle cell.

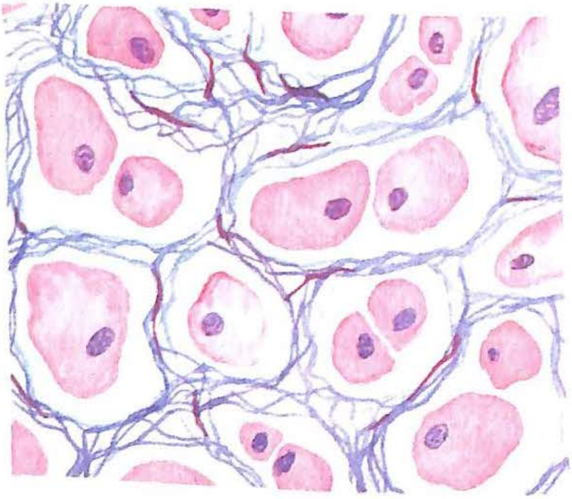
Both heart muscle cells and intestinal muscle cells are not under control of your brain. Most of the muscle cells in your arms, legs, face, and tongue are under control of your brain.

Cells That Support

Your ear doesn't hang down, does it? Why not?

Your ear is stiff and erect. Yet it has no bones in it. What holds it up?

Cells in the ear make a kind of material that supports the ear. This material is called **cartilage** (kär′tə·lij). Cells of the ear are surrounded by the



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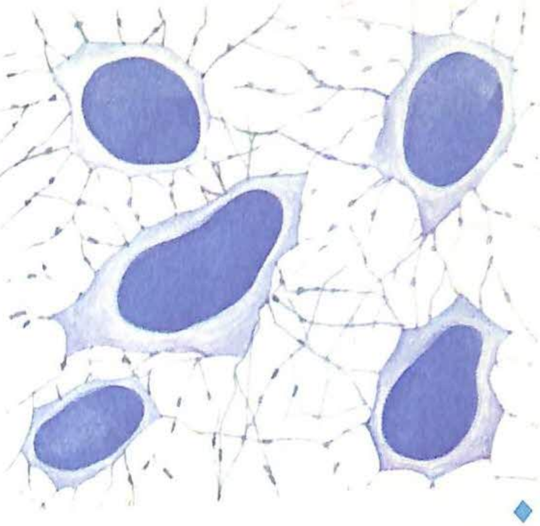
cartilage they make. ▲ Cartilage gives the ear stiffness. Cartilage gives your nose its shape, too.

Another kind of **supporting cell** allows you to stand straight. You can stand because you have bones, which support your body. The bones are made by **bone cells,** ◆ another kind of supporting cell. Bone cells might better be called bone-making cells. The cells make the hard bone that surrounds them.

There are other cells that provide support. Feel your knee just below the kneecap. There is a tough band there, called a **ligament** (lig′ə·mənt). A ligament is built of strong fiberlike cells. ★ It joins one bone to another. Now feel the inside of your elbow as you bend your arm. There is another tough connecting band here. This one is a **tendon** (ten′dən), a band of cells that joins bone to muscle.

Look back over the pictures of cells on these three pages you have just read. These cells look different from each other. These different kinds of cells have different jobs to do.

Yet these different-looking cells are alike, in certain ways. Each one of these cells has a nucleus, for example. Each one of these cells is made up of protoplasm, the living substance of cells. Each of these cells, no matter how different it appears from other cells, can make more cells like itself—can reproduce itself.



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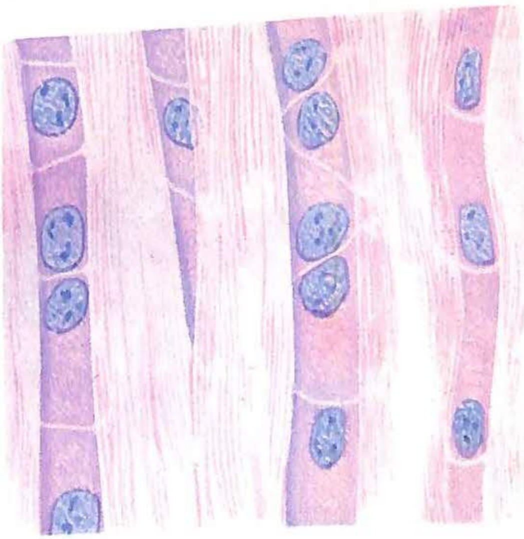
Cells That Carry Messages

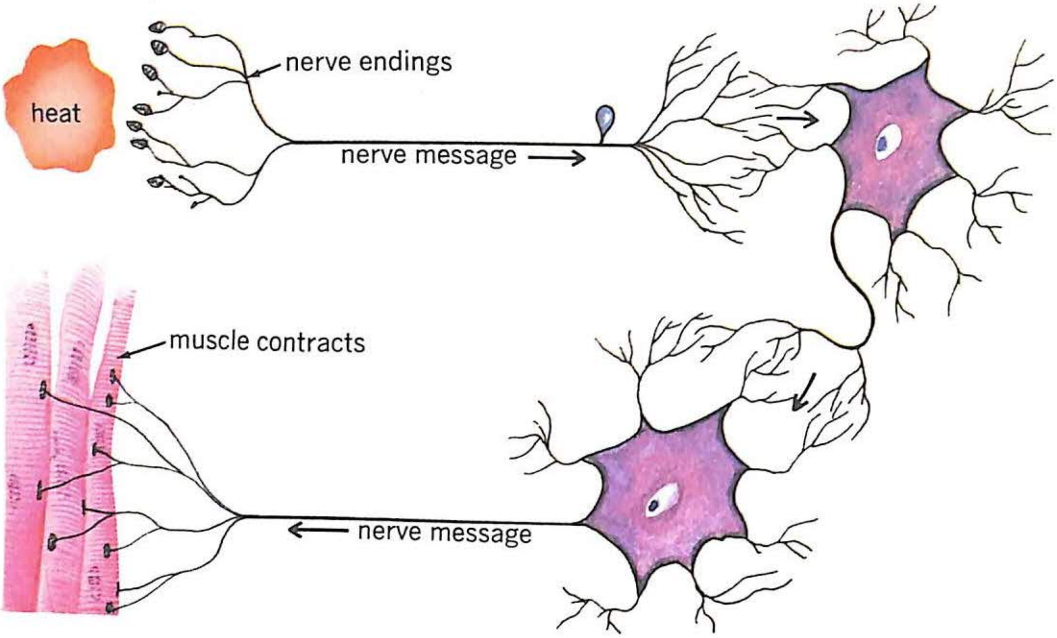
Wiggle a finger again.

How does the message "Wiggle a finger," get from your brain to the muscles of the finger that wiggles?

The message is carried by **nerves.** Each nerve is made up of thousands of nerve cells, or **neurons** (no͝or′ons). Each neuron that carries messages to the arms and legs has a long fiber

★



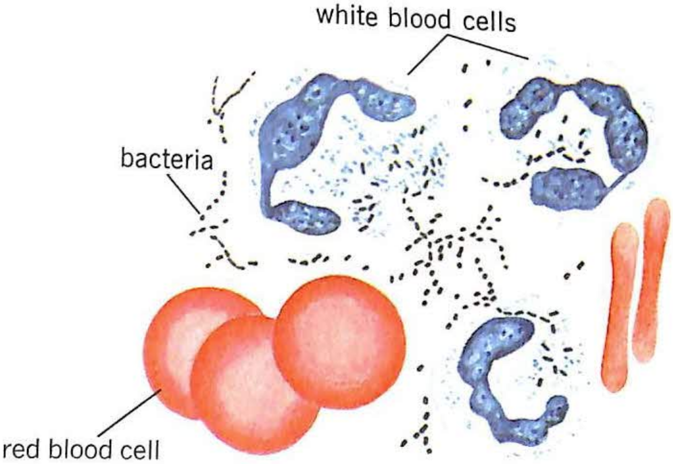


coming from its cell. One neuron passes a message it receives to another neuron across the ends of the fibers. ■

Messages are carried *from* the arms and legs, also. Suppose that you touch something hot. Even as you exclaim "Ouch!" your finger pulls back from the hot object. A neuron in the finger connects with a chain of neurons that carry the message to muscles in the finger. The muscles withdraw the finger, and a burn is prevented. It takes only a fraction of a second for the message to travel from neuron to neuron. We will see later what the message carried by neurons is like.

Cells in the Blood

You have about 3½ or 4 quarts of blood in you. Adults have from 5 to 6 quarts. Blood, too, is made up



of cells, **red blood cells** and **white blood cells.** ●

You may know that the red color of blood is given to it by an iron compound in the red blood cells. This compound is **hemoglobin** (hē′mə·glō′bin). The hemoglobin in a red blood cell carries oxygen to other cells in the body.

White blood cells can move about by themselves. When bacteria enter the body, white blood cells move toward them. Then the white cells "swallow" the bacteria, in much the same way as an ameba takes in food. ● In this way many bacteria are destroyed as soon as they enter the body. Destroyed bacteria may be thrown out of the body as pus. Pus is made up of living and dead white blood cells. The dead white cells are full of the bacteria that got into the body.

Cells Working Together

Put your hand beside this page and look at it. Look at the amazing collection of cells, all working together.

Skin cells cover your hand. Muscle cells move it. Bone cells support it. Red blood cells bring oxygen to every cell in it. White blood cells keep bacteria out of it. Cartilage cells tie its parts together. Nerve cells carry messages through it. Your hand is made up of groups of different kinds of cells working together.

A group of cells of the same kind and doing one kind of job is a **tissue** (tish′o͞o). Muscle cells, for example, make up *muscle tissue.* Nerve cells make up *nerve tissue.* The cells in the blood make up *blood tissue.* Cells that make bone, cartilage, ligaments, and tendons are called *supporting tissue.* They support the body. And the cells that cover, such as skin cells, are *covering tissue.* You have now met five kinds of tissues in the body:

covering tissue
supporting tissue
nerve tissue
muscle tissue
blood tissue

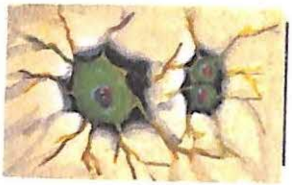
These different tissues work together, too. Your lungs, for instance, have covering tissue, muscle tissue, blood tissue, and nerve tissue. Recall that the lungs are an organ of the body, a part of the body which does a special job. The lungs, the liver, the stomach, the heart, are all organs. Each organ is made up of tissues. Each tissue is made up of cells. Cells work together in tissues and in organs.

You are as healthy as your cells. When your cells are healthy, so are the tissues and organs of your body. And so are you.

Keep in mind that your body is made up of many different kinds of living cells, all working together and keeping you alive and well.

BEFORE YOU GO ON Here are drawings of some cells like those in your body. See how many you can recognize.

1. Tell what sort of cell each is.
2. Tell what each sort of cell does.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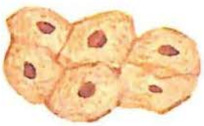
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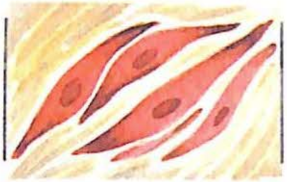
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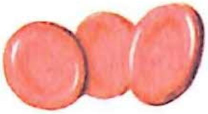
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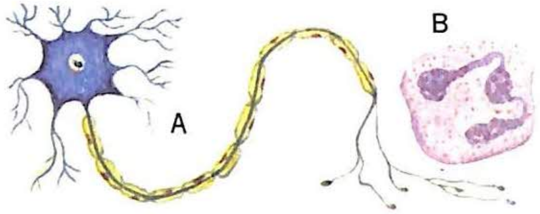
USING WHAT YOU KNOW Here are drawings of two cells found in a rabbit.

1. What tissues do they come from?
2. What does each cell do?



4. Within the Body

Your body is like a marvelous machine that takes in food and gives out energy. Its building blocks are billions of tiny cells, working together in tissues and in organs.

Organs work together too. Organs work together in teams called **organ systems.**

One organ system, for example, is made up of organs like the mouth, the stomach, and the intestine. The work of this system is digesting food, of course. Another organ system has to do with breathing. It is made up of organs like the nose, the throat, and the lungs, working together.

Organs work together in teams. *How* do organs work together? What does each member of a team do? In the illustrations that follow, you can study some of the organ systems of the body, and see for yourself.

In a way, we are putting the body together from its building blocks, you see. First we studied cells. Then we studied tissues, made up of cells working together. Next came organs, which are made up of tissues. Now we are about to see how organs work together in the body, in organ systems. See how the body's building blocks fit together:

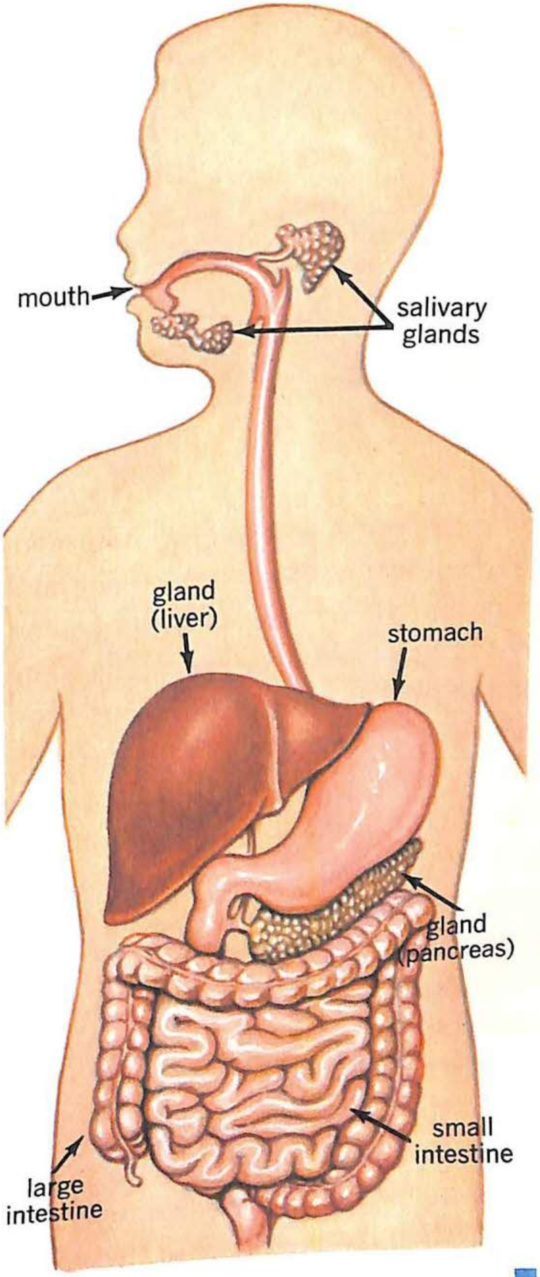
> Molecules form cells.
> Cells form tissues.
> Tissues form organs.
> Organs form organ systems.
> Organ systems form the body.

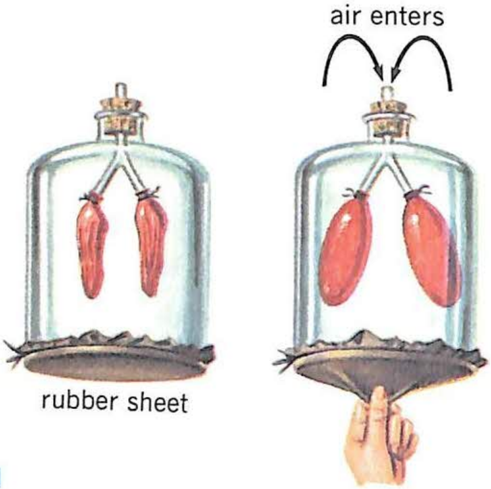
The body is beautifully organized to do a remarkable job.

A. Digestion—Making Food Ready for Cells

Cells need food. But every cell in your body is wrapped in a membrane. To get to a cell, food substances must pass through that cell membrane. To pass through the membrane, food substances must be broken down, that is, digested. The organs of your body that do the job of digesting food make up your **digestive system.** Let's look at some of the things that this system does. ■

When food is taken into the *mouth*, the tongue and teeth break it up. At the same time, juice is poured on the food. This juice is saliva. Saliva comes from **glands** that open into the mouth. Close your eyes and imagine that you can taste your favorite food. You may imagine an ice cream cone, a hot dog with mustard, or whatever you like best. This imaginary food may cause saliva to flow in your mouth, just as though you had some real food in your mouth. The saliva helps you





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to swallow food. Swallow now and you will swallow some saliva sent into your mouth by the **salivary** (sal′ə-ver′ē) glands. Saliva starts digestion of the food in the mouth, for it contains an enzyme. This enzyme can break down carbohydrates. So saliva is a digestive juice. It wets the food, too. Without saliva you would find it almost impossible to swallow!

From the mouth the food goes down a tube to the *stomach*. In the stomach the food is squeezed by strong muscles and broken up still more. Glands pour more digestive juices on the food. These digestive juices in the stomach break down proteins. Then the food goes to the *small intestine*.

The small intestine finishes the job of digestion. Glands in the small intestine make digestive juices that break down carbohydrates and proteins and fats still further. The food is finally digested in the small intestine. The food substances are dissolved. Now they can pass through membranes.

In the wall of the small intestine are tiny tubes. The walls of these tubes are very thin membranes, and the dissolved food passes through them. From these tubes the digested food is taken by the blood to all the cells of the body. Then dissolved food passes through the cell membrane into each cell.

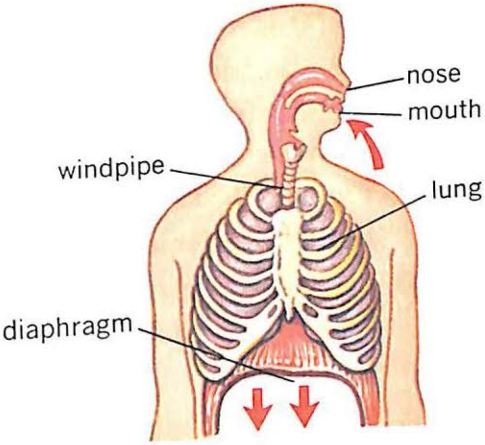
Food that is not digested does not pass through the walls of the tubes. It passes out of the body through the *large intestine*.

B. Breathing—Getting Enough Oxygen

Press your hand against the ribs just below your arms. Take a deep breath and let it out. Do you find that the ribs seem to move out as you inhale? And that they seem to move in as you exhale?

You might think that this movement happens because you breathe. But this is not so. Just the opposite is true. You breathe partly because of this movement! Let's look at a model and see what else happens.

This bottle has a sheet of rubber for a bottom, instead of glass. ■ The balloons are attached to glass tubing. Notice what happens when the rubber sheet is pulled down. More air has entered the balloons. When the rub-



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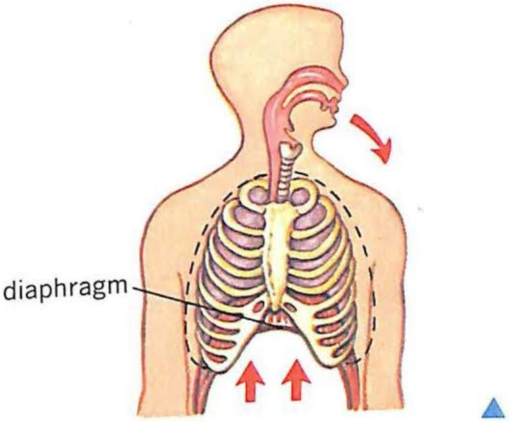

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ber sheet is pulled down, the space around the balloons becomes larger. This makes the air pressure in the bottle lower. The air outside the bottle has more pressure. It rushes into the balloons, and the balloons expand.

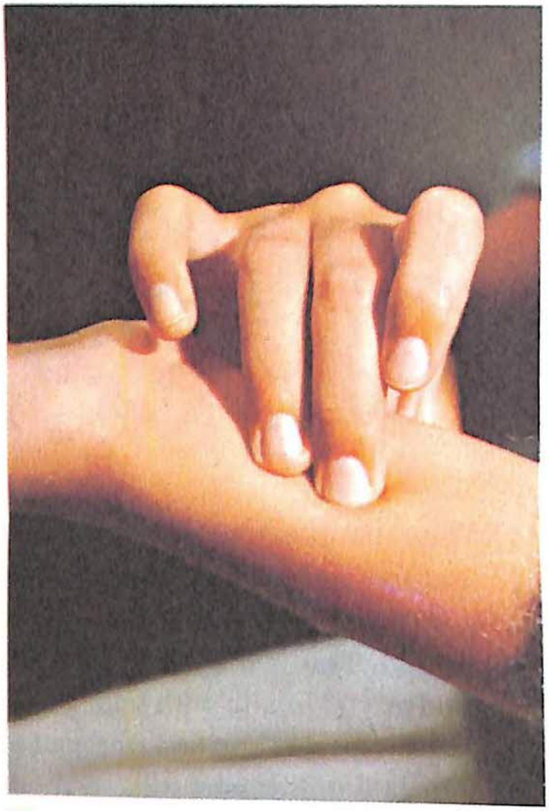
Strange to say, this is a model of what is happening inside you now as you breathe. The balloons are like your lungs. Think of the glass bottle as the ribs and muscles surrounding your lungs. And the stretched sheet of rubber is like your **diaphragm** (dī′ə-fram). The diaphragm is a sheet of muscles below the lungs.●

Recall what happens when the rubber sheet across the bottom of the bottle is pulled down. The muscles of the diaphragm can make the diaphragm move down, rather like the rubber sheet. When the diaphragm moves down, the space around the lungs becomes larger. Air rushes into the lungs just as it rushed into the balloons. The lungs expand.

When the diaphragm moves down, under the lungs, the ribs and muscles around the lungs move outward at the same time. This is the movement you can feel as you inhale with your hands on your ribs. It makes the space around the lungs larger still.

Then the diaphragm moves back up.▲ The ribs and muscles around the lungs move inward. The space around the lungs becomes smaller. Air is squeezed out of the lungs. The lungs contract, and you have exhaled. These organs of breathing make up the **respiratory** (ri·spīr′ə·tôr′ē) **system.**

Now let's follow the path of air from outside the body into the lungs. Air enters through the nose and travels down the windpipe. In the lungs the air becomes moist. The oxygen in the air dissolves in the moisture. Then this oxygen is able to pass through the very thin membrane of the lungs into the blood. The blood carries the oxygen to every cell.



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In each cell the oxygen is used in oxidation. That is, the oxygen is combined with carbon and hydrogen from food substances. This makes water and carbon dioxide, which pass out of the cell and into the blood. Now the blood carries carbon dioxide back to the lungs. The carbon dioxide passes through the membrane into the lungs, making the air in the lungs richer in carbon dioxide. We exhale the carbon dioxide.

C. Circulation— Getting Substances to Cells

Feel your pulse. Place the fingers of your right hand on the edge of your left wrist. ■

What is the beat you feel? It is the surge of your blood being pumped through your body. The bundle of muscles that is your heart is expanding and contracting, pumping blood. Each time your heart contracts, it forces blood into the **blood vessels,** tubes that carry the blood. The beat

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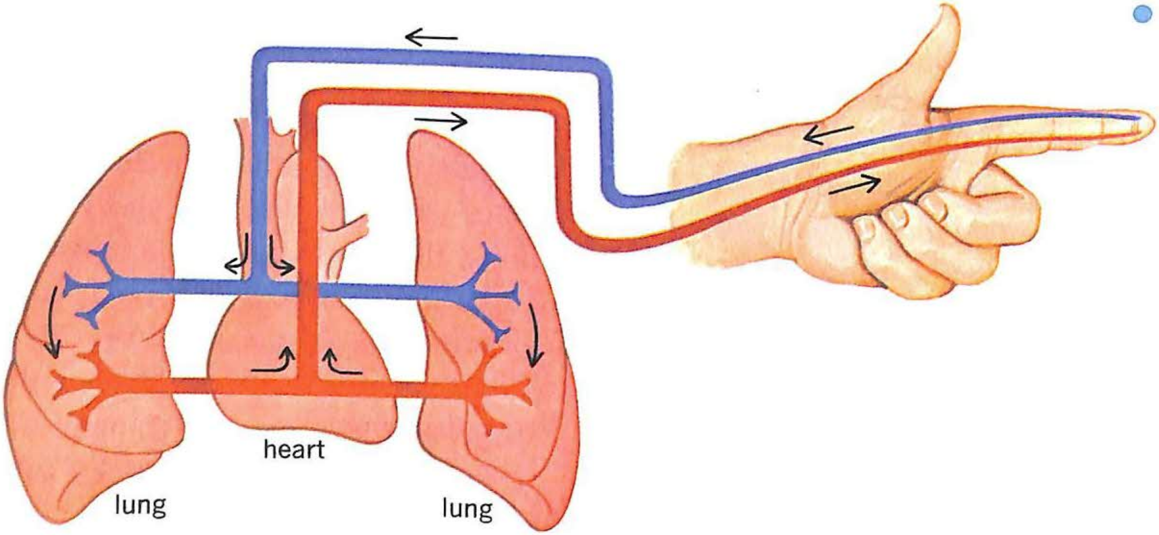


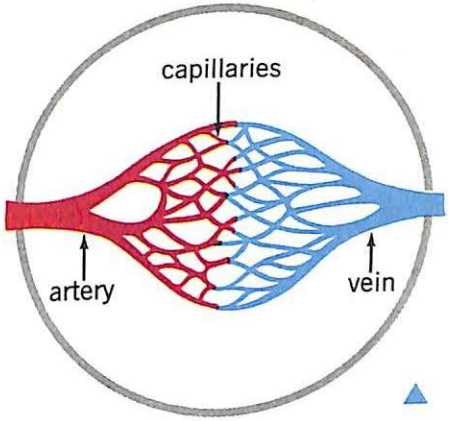
that you feel in your wrist is due to the contraction of your heart.

The blood you feel pulsing in your wrist is on its way to the fingers of your left hand. Trace the blood's path as shown in the diagram and see. ●

From your finger the blood goes to your heart. The heart pumps the blood to the lungs. From the lungs the blood goes back to the heart. Again the heart pumps the blood, this time out to the finger. From the finger the blood goes back again to the heart. And so over around and around, the blood **circulates** (sûr′kyə·lāts). This system of the heart and blood vessels is the **circulatory** (sûr′kyə·lə·tôr′ē) **system.**

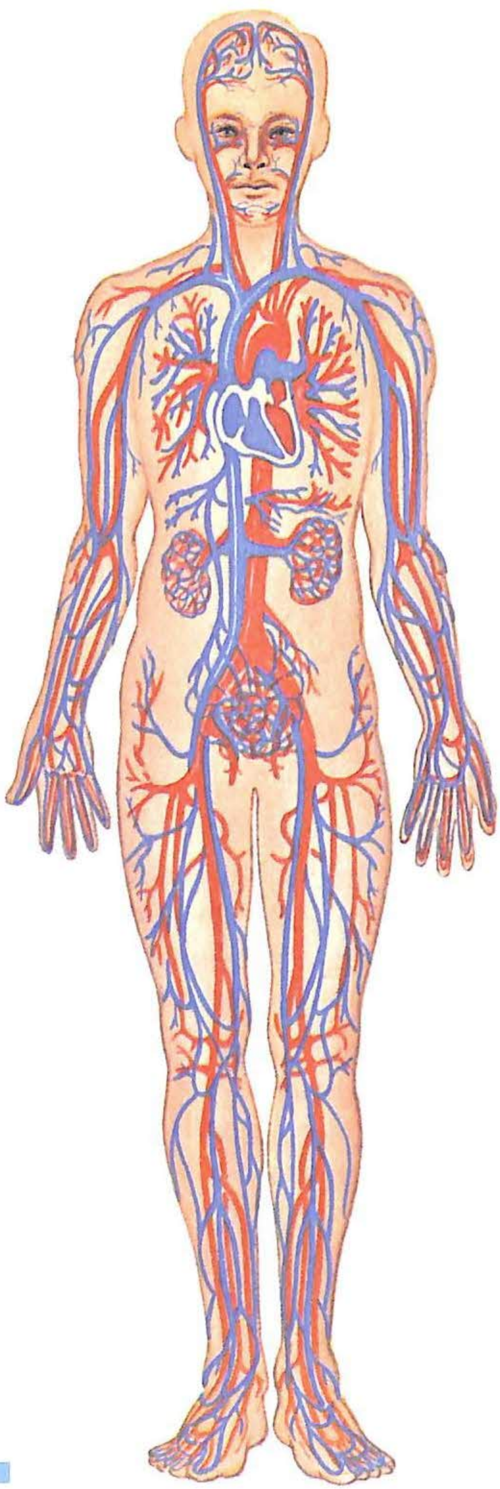
Let's see what is happening to the blood as it circulates. Blood is made up mainly of water, which has dissolved food substances in it. It has other substances in it as well, for instance, the red blood cells. Red blood cells have hemoglobin in them. In the lungs the hemoglobin combines with oxygen. When this happens the blood becomes bright red. So blood *leaving* the lungs is rich in oxygen and bright red in color. Its path from the lungs to the finger, by way of the heart, is colored red on the diagram.

In the finger the blood gives up oxygen to the cells, and takes up carbon dioxide. Then it starts back to the heart. So this returning blood has less oxygen. It is a dark red color. Its path is colored blue on the diagram. When it reaches the heart, this blood is sent to the lungs. There it receives more oxygen and becomes bright red again. Then it leaves on another round trip, through the blood vessels to every cell in your body and back again to the lungs.



▲

The bright red blood is carried by blood vessels called **arteries** (är′tər-ēz). The arteries carry blood to organs all over the body, to the kidneys, intestines, arms, legs, brain, and so forth. The arteries divide into smaller and smaller blood vessels. The smallest blood vessels are no wider than a hair and are called **capillaries** (kap′ə·ler′ēz).▲ It is in the capillaries that red blood cells pass oxygen to other cells. Now the blood has less oxygen and is dark red. It flows from the capillaries into blood vessels called **veins** (vāns). Veins carry blood back to the heart. On each round trip the blood exchanges materials with the cells.



■

As you can see in this drawing, your body is threaded through with blood vessels. ■ Arteries lead from the heart to all organs. Veins lead from the organs to the heart. Try tracing the circulation of blood from the heart to the brain, from the heart to a toe. No matter how long the path, or how many turns it makes, it is like the circulation to your finger.

D. Circulation—The Heart

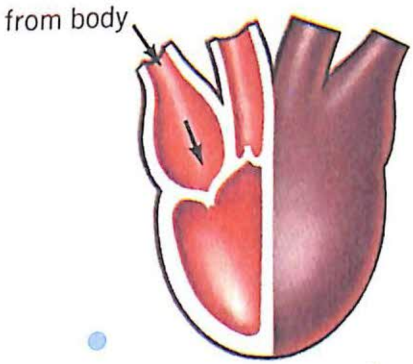
Put your hand over your heart. What is it that you feel beating? It is the powerful muscles of your heart contracting and expanding and forcing blood through your body. They do this about seventy times every minute, on the average.

Did you notice, when you were studying the circulation of the blood, that the heart pumps the blood *twice* on each round trip? First the heart pumps blood to the lungs. From the lungs the blood returns to the heart and is pumped again, this time to the body. In fact the heart is a double pump. Here's how it works.

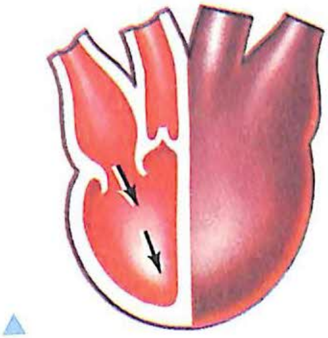
Blood flows to the heart through the veins. This blood is called venous (vē′nəs) blood. Venous blood is bluish-red in color, because it has less oxygen than the blood in arteries. It also carries carbon dioxide.

This venous blood enters a space in the heart called the right **auricle** (ôr′i·kəl). ●

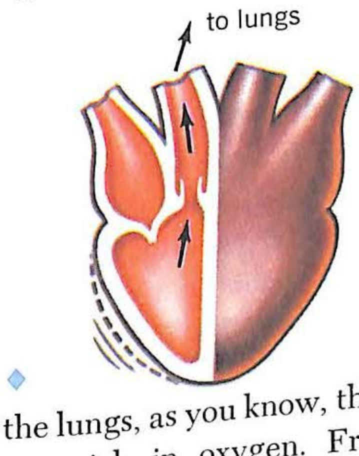
The blood stays in this auricle, on the right side of your heart, for a moment. Then the blood passes into



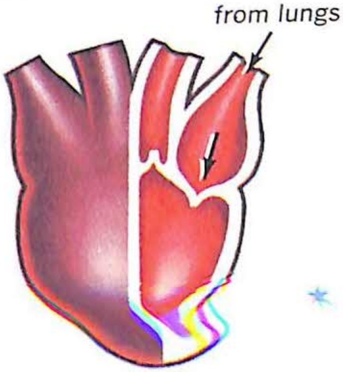
the space called the right ventricle (ven′trə·kəl). ▲



Now comes the movement which you feel as a heartbeat. The right ventricle contracts. Its heavy muscle squeezes the blood into a blood vessel leading to the lungs. ◆

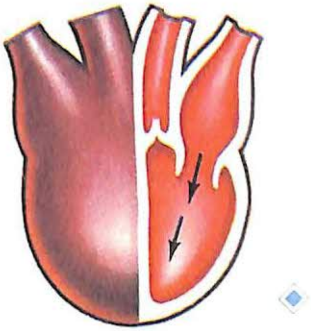


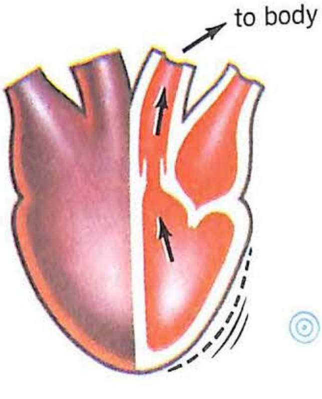
In the lungs, as you know, the blood becomes rich in oxygen. From the lungs bright red blood returns to the heart. This time the blood enters the left auricle.★

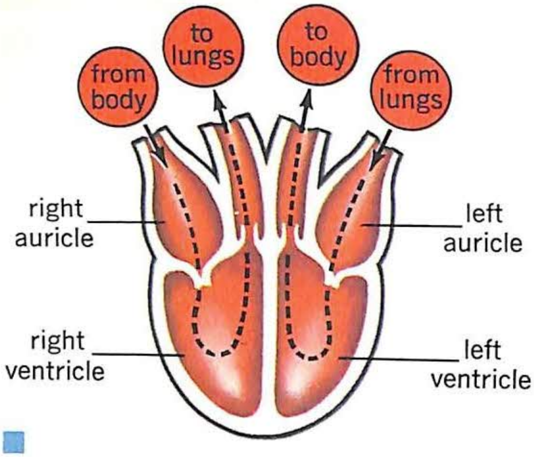


From the left auricle the blood goes to the left ventricle. ◆

The powerful muscle of the left ventricle contracts. Bright red blood surges from the heart into arteries leading to all parts of the body. ◎







■

As you see, the heart really is a double pump. The left auricle and left ventricle make up one pump, sending blood to the body. The right auricle and right ventricle make up the other pump, sending blood to the lungs. Both pumps work at the same time, of course, and in step. ■ As the right ventricle contracts, the left ventricle contracts too.

Each of these four spaces inside the heart has its own work to do, then, as shown below:

Right auricle	Receives venous blood from the body
Right ventricle	Sends the venous blood to the lungs
Left auricle	Receives oxygen-rich blood from the lungs
Left ventricle	Sends the oxygen-rich blood to the body

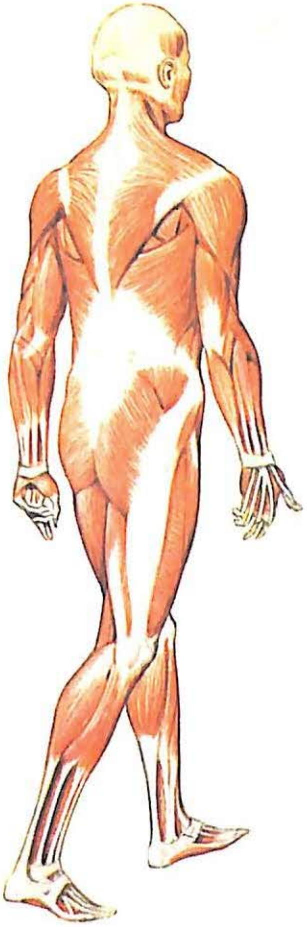
When a ventricle contracts, why isn't the blood forced back into the auricle it came from? Notice the **valves** that separate the auricles from the ventricles. Each valve is like a gate that allows blood to pass in one direction only. When a ventricle contracts, the valve to the auricle closes. The blood cannot back up into the auricle, and surges into the arteries.

Your heart is a remarkable organ. Its ventricles contract about seventy times in a minute, on the average. How many times have they contracted thus far in your life? About every 25 seconds your blood is sent once around your body. How many round trips has your blood made since this time yesterday?

E. Movement—The Muscles

Bend your knee. Lift a book. Walk. You do these things, and many more, without thinking about them. Your muscles are at work.

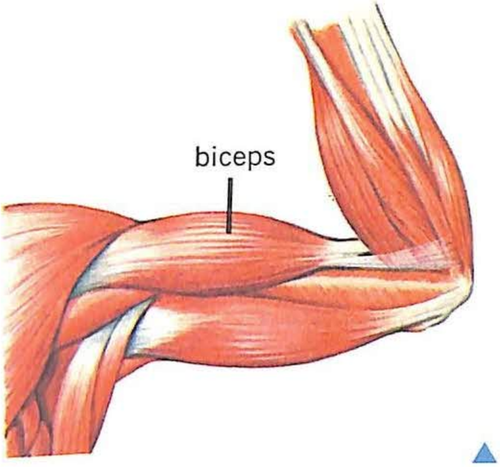
What are muscles like? How do they work together? Where are the main muscles of the body? You can see some of the answers to these questions in this drawing. (Muscles are red, tendons and ligaments are white.) ● Your body is clothed in muscles. They crisscross and overlap in many directions, as you see. It would be almost impossible to move if all of your muscles did not work together!



●

Look at this drawing of the muscle, called the *biceps* (bī′seps) in your arm. ▲ Move your arm back and forth and feel your biceps shorten and lengthen. When the long cells of the muscle shorten, the whole muscle shortens, or contracts. Muscles can exert a force when they contract. They cannot exert a force as they become longer.

Notice how the muscles in the shoulder crisscross and overlap. They enable the arm to move in all directions—up, down, sideways.



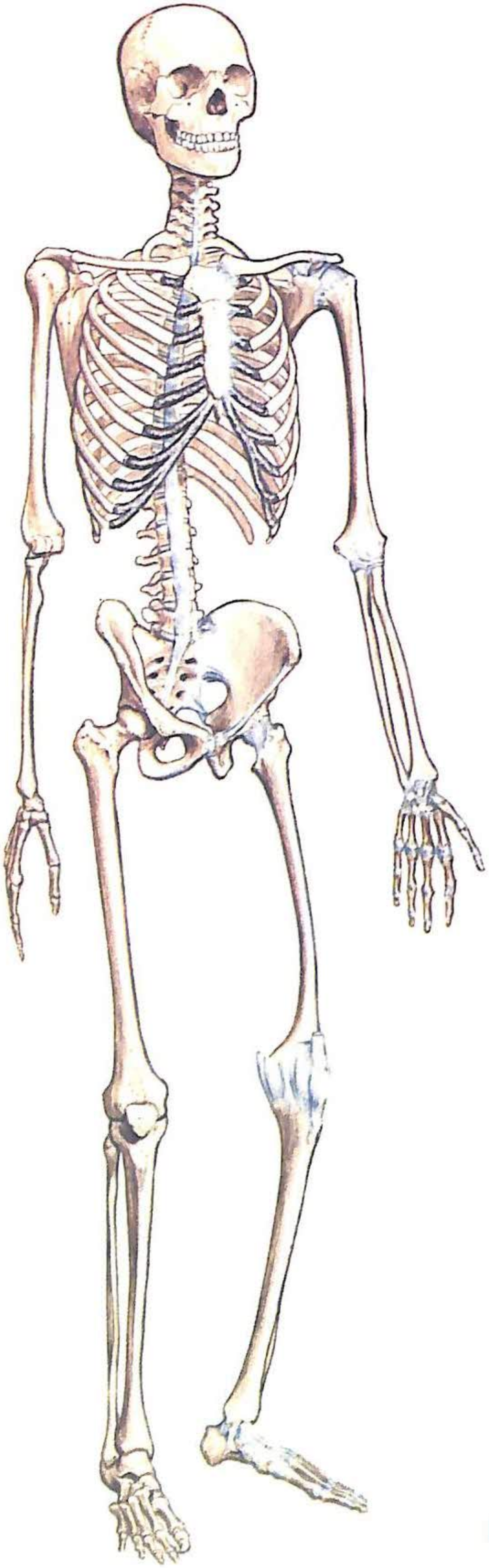
▲

The muscle in the calf of the leg is powerful. It raises the heel, and with it some part of the weight of the body. See how the end of the muscle is attached to the bones of the ankle by a very strong tendon.

There are many different muscles, as you can see. Yet all are alike in this way: each muscle is made up of a bundle of long muscle cells. ◆ The bundle is bound together by a tough membrane. All of your muscles make up your **muscular system.**

Your body is clothed in muscles.

◆



F. Support—The Skeleton

Think yourself fortunate to have a skeleton. ■

Some creatures do not have skeletons, you know. A beetle, for example, is held together by its hard outer case. It has no bones. Nor does a jellyfish. Such creatures are very limited in what they can do. A living thing that has a skeleton is not so limited.

Have you ever watched a high building being erected? Steel columns and girders are put in place first, making a kind of skeleton building. In fact the columns and girders are the skeleton of the building. They support its floors and walls and give it strength to stand erect. Your skeleton does much the same for you. It is the strong framework to which your organ systems are attached. All the bones in your body are parts of your **skeletal system.**

The skeleton does more than support the body. Look at the muscular system again (page 215) and notice how muscles are attached to the skeleton. Muscles exert a force when they contract. But the body moves because the muscles are fastened to, and move, the bones.

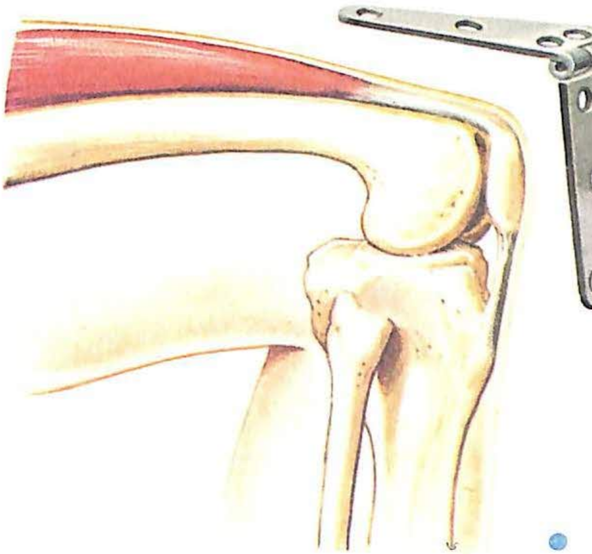
The steel skeleton of a skyscraper is rigid. As you well know, the bony skeleton of the body is not rigid. It can move about in an extraordinary number of ways! How is this managed? The skeleton can be moved because you have **joints.** They are the places where two bones come together. Bend your knee, and notice the *hinge joint* in it.● Can you locate other hinge joints in your skeleton?

If you will move your arm in a circle, you can observe another kind of joint of your skeleton in action. It is a *ball-and-socket joint.*▲ The ball, on the end of the arm bone, can turn in any direction in the socket in the shoulder. Where else is there a ball-and-socket joint on the skeleton?

You have a backbone that holds you erect. Yet you can bend your backbone. Your backbone is made up of pieces of bone called **vertebrae** (vûr′tə·brē).◆ Notice how they fit into one another. Each vertebra can move a little, so the backbone can bend. Yet it is a strong support.

Notice the opening in the vertebra. Through these openings runs the spinal cord, or nerve cord. Even when the backbone bends, your spinal cord is well protected inside the vertebrae.

Here is yet another important task that the skeleton performs. As all cells do, red blood cells die and have to be replaced. Inside some bones is **bone marrow** (mar′ō). The bone marrow manufactures new red blood cells to be circulated in the blood stream.



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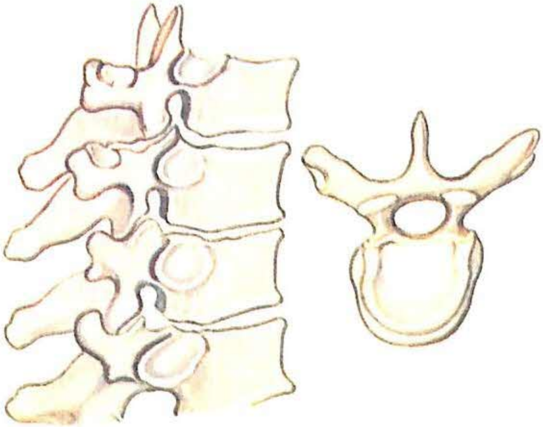

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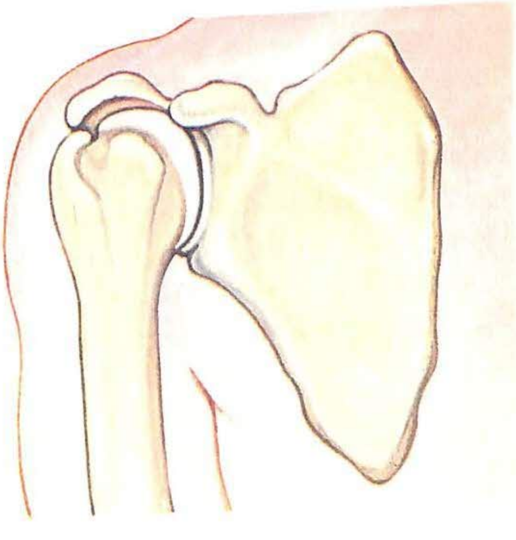

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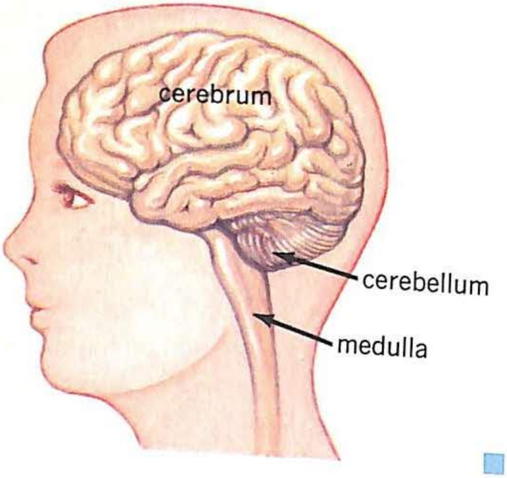


G. Nerves—Coordinating the Body

Try this. Take a pencil in your hand. Close your eyes. Feel what you have in your hand. You can still tell that it is a pencil.

How can you tell?

In the tips of your fingers are nerve endings like those shown on page 204. These nerve endings join together to make up a **sensory** (sen′sər·ē) **nerve.** The sensory nerves carry messages about the pencil in your hand, from the fingers to the brain.

Sensory nerves of the eyes sense light and carry messages to the brain, where a picture of what you see is put together. The sensory nerves of the ear sense sound and carry messages about sound to the brain.

Some sensory nerves, especially those beginning in the legs and arms, lead to the spinal cord in the backbone. So do some sensory nerves from muscles. And there are nerves that carry messages *from* the spinal cord to muscles. These nerves are called **motor nerves.** When a muscle receives a message from a motor nerve, the muscle contracts.

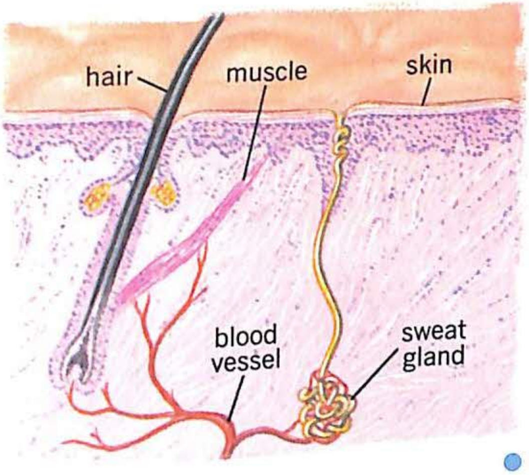
The brain itself is divided into parts, each with its work. The **cerebrum** (ser′ə·brəm) is the part of the brain where thinking takes place. ■ The **cerebellum** (ser′ə·bel′əm) controls muscles so that they work together. The **medulla** (mə·dul′ə) is very important too; from it and to it go the nerves that control breathing and heartbeat.

Your brain and spinal cord are the center of your **nervous system.** It is your nervous system which keeps all the parts of your body working together.

H. Excretion—Getting Rid of Wastes

When you breathe on a mirror, moisture collects on the glass, and you know that this means your body is getting rid of water. Your body is getting rid of carbon dioxide as well, when you breathe out. The water and the carbon dioxide are waste substances produced by your body.

Where do these wastes come from? Remember that carbon dioxide and water are produced in your cells as oxidation goes on. When these wastes are given off, we say that **excretion** (iks·krē′shən) is taking place. In other words, cells excrete carbon dioxide and water.



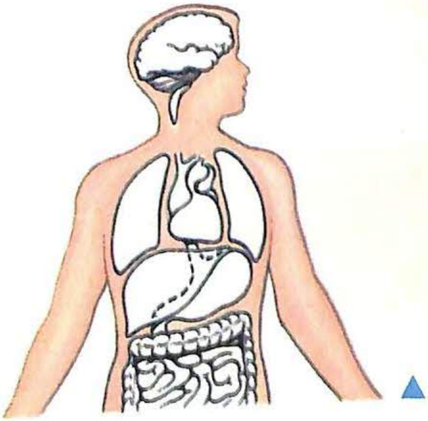
●

It is just as important for a cell to excrete waste substances as to take in food substances. If either function stops, the cell dies.

Let's look at some of the ways in which the body gets rid of wastes. Carbon dioxide and water, for instance, leave the body through the lungs. The lungs are organs of excretion, biologists say. The skin is an organ of excretion also. You notice this particularly on hot days when sweat flows freely! This means that the body is excreting wastes through the sweat glands in the skin.● Notice the coiled shape of the gland. It not only excretes water but substances such as salt. Only the salt that the body does not use is excreted.

The kidneys are another organ of excretion. Organs that work together to get rid of body wastes make up the **excretory system.** Blood passing through the kidneys gets rid of water and certain other substances. A special waste substance of cells that is excreted through the kidneys is *urea* (yo͝o·rē′ə). Urea can quickly poison a cell if not removed.

Excreting wastes is a highly important job of your lungs, skin, and kidneys. Unless wastes are excreted, your body cannot work properly. Waste substances can poison the body if not excreted. We know that the cells of the body must take in food substances to live. It is just as necessary for the cells to excrete waste substances.



▲

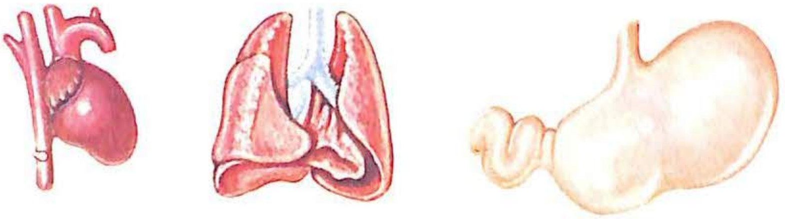
BEFORE YOU GO ON

1. Name the organs shown in the diagram.▲
2. Write a sentence or two about the work of each organ named.

USING WHAT YOU KNOW

1. Here is a diagram of some organs in the body of a rat. Can you identify them?

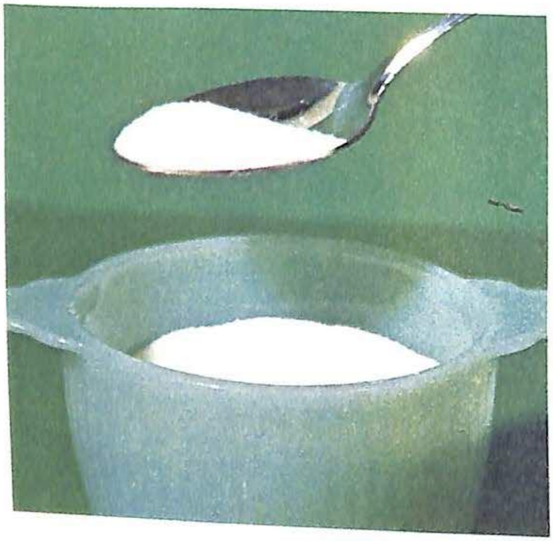
2. What is the function of each of these organs?



5. The Main Concept: The Body

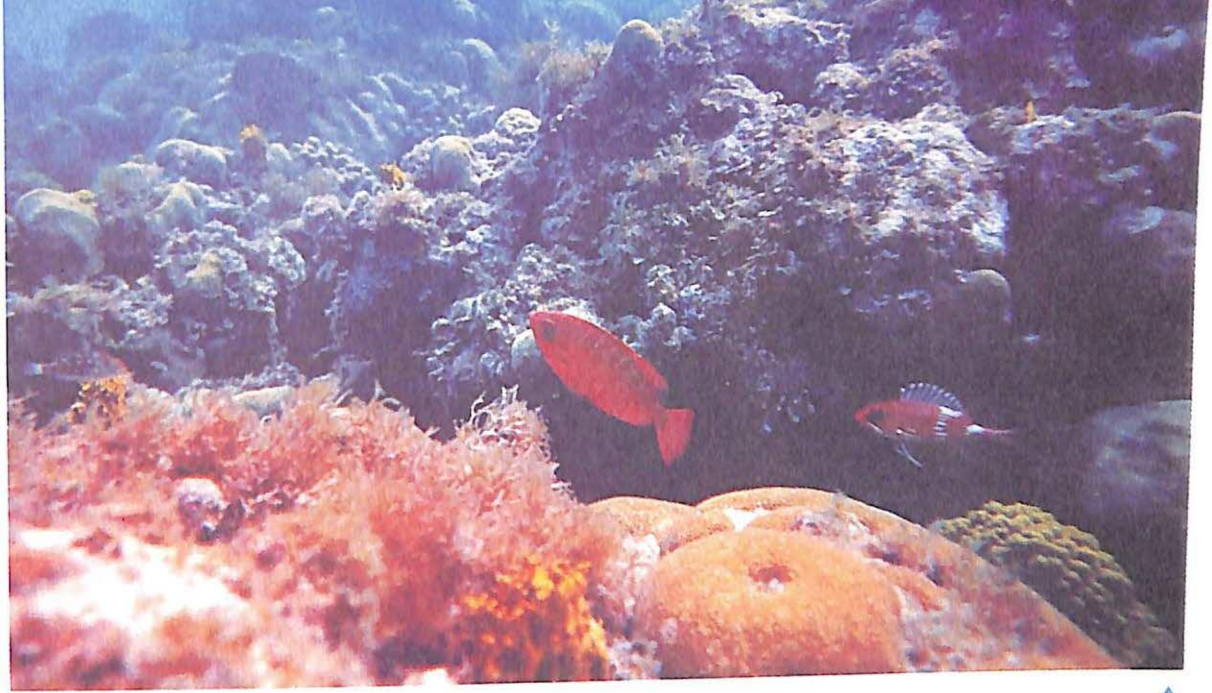
Look at this bowl of sugar. Take away a spoonful of sugar, and what remains is still a bowl of sugar. For a bowl of sugar is just a collection of tiny lumps. Taking away a part of the collection makes no difference to the rest.

But now look at a living thing—yourself, for instance. Your skeleton is not just a collection of bones. The bones are joined together, one working with another. Your digestive system is not just a collection of parts. Food tube, stomach, and intestines work together. Food taken into the mouth is made ready for the stomach; food in the stomach is made ready for the intestines. The parts of the digestive system work together. Your cells are grouped in tissues, tissues are grouped in organs, organs are grouped in organ systems. Cells, tissues, organs work together, all doing their jobs. All the parts of the body work together. Each part depends on every other part. *The body is organized.*



Indeed, every living thing is organized—for living. If some part is taken away, what remains is somehow changed. If some part of the sugar in the bowl is taken away, however, the sugar that remains is *not* changed.

Think of a frog, for example. Its parts are organized for living. But if



▲

the frog's heart stops, the frog can no longer carry on its **life activities.** It is no longer organized for the work of living. The heart no longer pumps blood to the cells. The cells get no oxygen and no food. The body gets no energy. The frog dies. Its life activities stop.

The parts of a plant are organized for living too. What happens if a plant's roots are damaged? The plant is no longer organized to do the work of a plant. It cannot carry on its life activities properly.

Any living thing is organized. It is organized to carry on its life activities. So the loss of any part makes a difference. The bits of sugar in a sugar bowl are not organized in this way at all, you can see. The loss of part of the sugar makes no difference in what remains. The sugar in the bowl remains sugar.

A living thing is organized to carry on its life activities. But we must add one thing more. A living thing is organized to live in a certain **environment.**

A fish can live in water. It can make use of oxygen dissolved in water, and its tail and fins enable it to move about in water. We say that a fish is **adapted** to live in water. This means that its organ systems are organized for life activities in the environment. ▲ Thus, a fish has organ systems which adapt it to live in a water environment.

Most birds are adapted for flight. So are many insects. Man's body is not adapted for flight. That is, man's body is not organized for flight. The fish is adapted to a water environment. Man is adapted to a land environment. Every living thing is adapted to the environment in which it lives.

Whenever you see a living thing, and want to understand its way of life, ask yourself these questions: How is this living thing organized to carry on its life activities? What sort of environment does it live in? How is it adapted to its environment?

Robins, roses, dandelions, dogs, fishes, frogs, every living thing lives in a special environment. Every living thing is adapted to its special environment.

Every single one.

Fixing the Main Concepts

TESTING YOURSELF

A. Test your understanding of important concepts in this unit by doing these problems.

1. Here is a list of three types of cells. Two of them belong to the same kind of tissue, one does not. Which one does not? What is the reason for your choice?

cell of skin
cell inside the cheek
muscle cell

2. Cells form tissues. Tissues form organs. Organs form systems, such as the nervous system.

From the following list of cells, choose at least three cells you expect to find in one tissue. What is the tissue? What is the reason for your choice?

red blood cell
bone cell
white blood cell
ligament cell
tendon cell
neuron
muscle cell
cartilage cell

3. At least three of the organs listed below are found in one system. What is the system? What is the reason for your choice?

heart
salivary gland
stomach
lungs
large intestine
brain
small intestine
diaphragm

4. Imagine a red blood cell in a vein of your left leg. Trace the travels of that red blood cell from the left leg and back again.

B. Test your understanding of concepts in this unit by using each of these key words and phrases in a sentence.

cell
tissue
organ
system
red blood cell
white blood cell
enzyme
muscle cell
neuron
bone cell
muscular system
circulatory system
digestive system
respiratory system
skeletal system
capillary

C. Test your knowledge with this quick check.

1. Blood with the most oxygen will be found in blood vessels

a. in the intestine
b. going to the lungs
c. in the legs
d. coming from the lungs

2. Proteins, fats, and carbohydrates in food enter the mouth. They enter the blood completely digested in the

a. mouth
b. stomach
c. large intestine
d. small intestine

3. One of these cells is not adapted to the same work as the others. This cell is the

a. cheek cell
b. skin cell
c. white blood cell

4. Enzymes help in the digestion of food. The importance of digestion is that it gets the molecules of food into the

a. blood
b. bones
c. cells
d. intestines

FOR YOUR READING

These books will give you more interesting information about the way your body works.

1. *Lifeline: The Story of Your Circulatory System* by Leo Schneider, published by Harcourt, Brace & World, New York, 1958. This book gives a good account of the way the circulatory system works.

2. *The First Book of the Human Senses,* by Gene Liberty, published by Watts, New York, 1961. To learn more about how you sense your environment, try this interesting book. How we hear, see, and feel are carefully explained.

3. *How Your Body Works,* by Herman and Nina Schneider, published by W. R. Scott, New York, 1949. You have already learned a good deal about how your body functions. This book gives you another view.

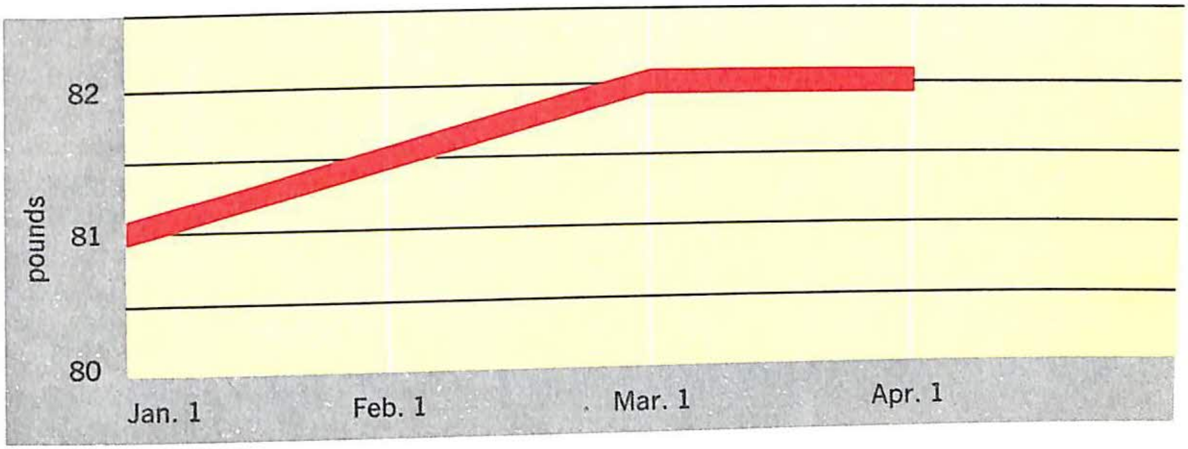
4. *Mice, Men and Elephants,* a book about the mammals by Herbert S. Zim, published by Harcourt, Brace & World, New York, 1942. An interesting and informative book about such things as how the heart works and how the brain functions. With many drawings and photographs.

ON YOUR OWN

An Investigation

Do you grow steadily or in spurts? Do you grow the same amount every month? Or do you suddenly shoot up every three months or so? Investigate yourself. Compare your records with those of other students of your age. Then you will be able to find out whether what is happening is true of other boys or girls of your age.

You can investigate the weekly changes in your height or weight for a period of 6 months. Recording your changes will be important because you will want to compare your growth with others. You might record the changes in a *graph*, like this. The lower line marks the time. The line on the left marks the height (or weight). Here is the record of one boy, for example.



How much did he weigh on the first day of February? How much did he weigh on the first day of March? Has he gained weight?

What would a graph of *your* growth look like?

CONCEPTUAL SCHEME

Living things are interdependent with one another and with their environment.

Unit Six

GREEN CELLS AS BUILDING BLOCKS

Text Pages 226–264)

NIT CONCEPT

he capture of radiant energy by reen plants is basic to the growth nd maintenance of all living hings.

A Preview of the Concepts

Children strengthen their understanding that green plant cells perform special functions without which life could not go on. They deepen appreciation for the plant processes which daily trap and convert the Sun's radiant energy and store it in foods, fuels, fibers, and vitamins.

A VIEW OF THE UNIT

The units up to this point have contained a number of investigations for the children to perform as they search for understanding of main concepts and subconcepts. They have sometimes planned investigations and set up equipment on their own, but more often than not they have followed directions given them and they have, themselves, uncovered essential bits of information that advanced their progress toward formulation of a concept, or big idea.

As this unit opens, the children become aware that problems to investigate really arise when they are confronted with a situation which they want to explain. The investigational process then follows orderly steps that often result in other questions for investigation being raised before a satisfying explanation can be found. The science classroom, after all, is a place for creating situations through which a concept is uncovered. Children's awareness of the procedures of investigation is developed by their analysis of the steps that Joan Waterman, a student in school, followed when she became curious about bubbles she saw rising from green plants in an aquarium.

The text purposely does not use the word *experiment* for the many investigations the children perform. A true experiment is a complex of many investigations performed many times in many ways under many conditions involving controls of many kinds. Joan's investigation was nearer to a true experiment than most investigations many children will be making, but, nevertheless, she was investigating.

The present unit builds understanding of methods of investigation while giving children understanding and appreciation for the role of green plants in the environment.

Children draw upon earlier units to move toward the concept that green cells are the builders of products essential to the life and growth of all living things. For example, Unit Two introduced the child to the following concept that helps him understand the process of photosynthesis: When matter and energy are transformed (in photosynthesis), the total amount of matter and energy remains unchanged. In Unit Four children gained understanding of the concept that living things interchange matter and energy in the environment. How do green plants do this? How are animals dependent on green plants? What has photosynthesis meant through the ages? These are some of the questions children explore in seeking to understand that the capture of energy by green plants is basic to the growth and maintenance of all living things.

A plant is sealed into a test-tube environment (Section 3). It lives and grows. An animal, a snail, is later sealed in with the plants. Both live and grow. By reasoning from the concept of interchange of matter and energy, children grow toward the understanding that a fish, a cow —even they—are sealed into an environment, Earth and its surrounding atmosphere.

Plants make carbohydrates. Are these enough for life? Children infer the importance of vitamins and minerals in the daily diet; again they realize that living things are dependent on green plants. Minerals from the soil enter the plants through the root-hair membranes; thus, children reevaluate the concept of diffusion developed in an earlier unit.

The concept of oxidation, referred to in every earlier unit, is also found to be important as living things use the food stored by photosynthesis, and as man releases the energy stored by the same process in fossil fuels many millions of years ago.

Interrelating Concepts

In this unit, many opportunities are offered to build upon and to interrelate concepts. Encourage children to recall the concepts they have learned. In the diversity of concepts in science there is unity. Unit Six foreshadows the long development of the great diversity in the forms of life on Earth, more fully recorded in Unit Eight. Green plants interchange matter and energy in the environment; plants and animals are interdependent with one another and with their environment; the total amount of matter and energy in the universe remains unchanged—yet change is the one constant that remains unchanged. These concepts all have a bearing on the capture of energy by green plants and the conceptual scheme that living things are interdependent with one another and with the environment.

SUPPLEMENTARY AIDS

Films

All the films and filmstrips are in full color. Names and addresses of distributors and suppliers are on page F–25.

Balance of Life and the Space Age (13½ min.), F.A. Considers the Earth's living things in terms of their basic needs. Interdependence of plants and animals is called a balanced system. For space journeys it will be necessary to create a balanced system inside a space capsule to keep astronauts alive. (Intermediate)

The Sun's Energy (12 min.), Cenco, 1963. Energy from the Sun makes life possible—causes plants to grow through photosynthesis. All our energy comes directly or indirectly from the Sun. Fuels release stored energy. Man is seeking to find better ways of using the energy from the Sun. (Intermediate, Junior High)

Filmstrips

Importance of Air in Nature (39 frames), Jam Handy, 1961. Simple investigations explain clearly the importance of oxygen to green plants and to man; oxygen carbon-dioxide cycle, nitrogen cycle, water cycle. (Junior High)

Roll Call of Plants (42 frames), McGraw-Hill, 1957. Explains different kinds of plants: algae; fungi; plants with true leaves, stems, and roots; seed-bearing and flowering plants. Shows the value of chlorophyll. (Intermediate)

Wealth from Mother Earth (42 frames), McGraw-Hill, 1959. Almost everything we use in our everyday life comes from things we find in Earth's crust. Shows formation of coal, oil, and natural gas from prehistoric plants and animals. (Intermediate)

Your Changing World (50 frames), McGraw-Hill, 1951. Concept of chemical change in oxidation; making of starch by green plants in sunlight by photosynthesis. (Intermediate)

Photosynthesis (42 frames), McGraw-Hill, 1953. Deals with basic scientific principles and processes; develops idea of photosynthesis. (Intermediate)

Plant Factories (48 frames), S.V.E. How green plants make their own food. Why they are vital to animal life. Step-by-step explanations. (Intermediate)

Science Reading Table

Starred titles are especially recommended for their content and readability. Names and addresses of the publishers are on page F–24.

**About Grasses, Grains, and Canes* by Melvin John Uhl, Melmont, 1964. Grass, as a botanical family, is briefly described and illustrated. The tremendous importance of grasses to mankind over thousands of years and under various methods of cultivation is emphasized. Illustrations in all sections are both beautiful and descriptive. (Average)

**Flowers and What They Are* by Mary Elting, Whitman, 1961. Concise but highly informative treatment of flowers in relationship to the entire plant and its growth. Structure and function of flowers are described by interesting narrative and excellent diagrams. Unusual activities and uses of flowers plus a brief account of Burbank's work. (Average)

Green Thumbs by Donald Nasca, F.A. Owen, 1964, from the Science Discovery series. Information about plants, their structures and functions, is interwoven in a story of the gardening activities of a brother and sister. Brief survey of topics such as seed dispersal and types of plants. (Easy)

Junior Science Book of Trees by Robert S. Lemmon, Garrard Press, 1960. Growth of an oak tree exemplifies growth and root function of trees in general. Photosynthesis, reproduction, and seed dispersal are described. Brief account of the ways trees are useful to man is included. (Average)

°*Plants of Woodland and Wayside* by Su Zan Noguchi Swain, Doubleday, 1958. A comprehensive study of botany with aids to identification of 100 wildflowers. Plant phyla, plant evolution, reproduction, and physiology are described. Short descriptions and drawings of many wildflowers make up a portion of the book. (Advanced)

Trees and How They Grow by Katharine Carter, Whitman, 1961. The structure and function of the principal parts of trees are described concisely and illustrated with drawings of normal and microscopic views. Included is material on types of trees, reproductive methods, and uses of trees by man. (Average)

Under a Green Roof: Animals and Birds of Our Woods by Anne Marie Jauss, Lippincott, 1960. Concise presentation of principal animals and birds of the woodlands of eastern, southern, southwest, Pacific Coast, and Alaskan areas of the United States and Puerto Rico. Description of habitats and activities relate the creatures to particular environments. (Average)

°*The Wonders of Seeds* by Alfred Stefferud, Harcourt, Brace & World, 1956. Deals with the formation, structure, and germination of seeds. Includes account of some of Mendel's work in genetics, and the story of the lotus seeds which, after lying dormant for one thousand years, developed into plants. Some attention is given to scientific methods of discovery. (Advanced)

°*Young America's Garden Book* by Louise Bush-Brown, Scribner's, 1962. A comprehensive and carefully planned series of projects for young gardeners. Includes chapters on the art, craft, and science of gardening and describes the soil, sunlight, water, planting, and care necessary to achieve the rewards and pleasure of gardening. Less capable readers will find this book useful for study of selected or assigned projects. (Average)

▶ INTRODUCING THE UNIT

How many kinds of green plants can you name? How many could you bring to class, in one form or another? From the latter part of the query, the idea of plant products could occur to some children. If season and locality permit, an informal "plant fair" or "flower show" might be initiated as an introductory activity to be developed during the unit and displayed near the end of the work. Such an activity will draw attention to the diversity among green plants.

What if there were no plants? What difference would it make? What can every geranium do that no person has yet been able to do? How is the geranium—and all other green plants—able to do it? Children are thus confronted with the need for investigating photosynthesis, the basic role of green plants.

(*Text pages 228–233*)

SUBCONCEPT

During photosynthesis (the manufacture of carbohydrates), green plants produce oxygen.

Section 1: JOAN INVESTIGATES

Children's understanding of the role of careful planning in scientific investigation is enlarged and reinforced.

Introducing the Concept

If you do not know the answer to a question, how do you find it? How do workers in science find explanations for things they do not yet know how to explain?

Most persons think that scientists spend their time investigating or experimenting in a laboratory. What do you think? Where do you think a scientist gets his problems? How does he know when he needs to investigate by working in a laboratory? For a true investigation do scientists know the explanation before they start? Do they have hunches? How do they check these hunches or educated guesses? Do they always go to a laboratory, or do they often use other methods?

Why are wondering and investigating important parts of scientific discovery?

Let's read about a girl who spent some time thinking about something she noticed. Children may now be encouraged to read the entire section which tells of Joan Waterman's investigation.

Children, in relation to their study of the concept, begin to appreciate the problems that interest a scientist and some of the methods he uses in trying to solve them.

Developing the Concept

Methods of discovery. Do scientists spend time wondering? Do they spend time thinking and using their imagination? (Of course they do.) Where do their problems come from? Where did Joan's problem come from? From her reading in a textbook? Most often scientists' problems come from observations for which no satisfactory explanation has been found or tested.

It is important that children understand that scientists seek answers for what is unknown or unexplained and that they use many methods of working. From Joan's work, what do you think the methods of a scientist would be once he recognized a problem? Answers may include the following, with variations.

1. They state the problem clearly. (That is, they try to clarify the problem on the basis of what they already know or have thought about for some time.)
2. They read books and confer with others. (If others have already worked on the problem, the problem may be fully answered and no additional work will have to be done.)
3. They consider all possible methods of arriving at a solution.
4. They perform investigations, record observations carefully, and repeat their work many times.
5. They make their methods, observations, and conclusions available to others for retesting.

Processes emphasized

Analysis of methods of the scientist
Investigation (with design of experiment)
Inference
Hypothesizing

Which of these methods did Joan Waterman use in her investigation? Some children may find it fun to show what Joan did by drawing cartoon diagrams as they read. The diagrams could show that: Joan noticed, Joan remembered, Joan wondered, and so forth.

What did Joan discover? Would she have succeeded on a rainy day? Did she find out on her first try? Why did she go twice to the library? How did she test her hypothesis that plants give off oxygen in sunlight? We say her investigation succeeded because she learned the answer to her problem. What connection do you see between her library work and her investigations? Would you conclude that scientists spend more time investigating than reading or more time reading than investigating? (The latter.)

Can we now list next to the listed methods of scientific discovery all the things that Joan did? What do you notice? Did Joan use all the methods of discovery that we listed?

Animals are dependent on the oxygen green plants give off during photosynthesis.

Joan's investigation and Joseph Priestley. As children read the story of Priestley's "Lively Mouse" (text page 231), ask them to recall from Unit Two, pages 73–74, what they learned about the air they inhale and the air they exhale. Chart the information, through questioning, for green plants and for animals. The chart might look like this:

	Green Plants	**Animals**
Produce	oxygen	carbon dioxide
Test	glowing splinter bursts into flame	limewater turns milky

Why did Priestley's mouse in the closed jar need the green plant?

All living things depend on a continuous supply of oxygen.

Ventilating a room. What does Priestley's experiment have to do with you? For example, have you ever felt drowsy and unable to work well in a stuffy, closed room? What does the room need? (Oxygen.) How can you get oxygen into the room? To demonstrate room ventilation, set the end of a piece of rope from a clothesline aflame and then extinguish it. Open a window from top and bottom. Hold the smoking clothesline close to the bottom opening. The path of the smoke indicates inflow of air. Fastened to a window stick, the smoking rope will show outflow at the top. The air that comes in at the bottom is cooler and heavier than the air in the room. It pushes the warmer and lighter air out at the top. Children interested in why air flows in this way may look up convection currents in a reference book. You may also wish to consult *A Sourcebook for Elementary Science,* pages 304–307, for further insight into the principles of convection.

Extending the Concept

Commercial uses of oxygen. Joan's test for oxygen should give you a clue to why there are "No Smoking" signs in hospitals when a patient is in an oxygen tent. The oxygen in Joan's test tube burst into flame when she inserted the glowing splinter. Oxygen supports burning. In its pure form it combines readily with other substances; a glowing spark is all that is needed to start combustion (rapid oxidation). Nitrogen in the air keeps oxygen from combining rapidly. Why is commercial oxygen kept in heavy metal cylinders? (To keep it from escaping into the air and to reduce fire hazards in its use.) You may be interested to check the "yellow pages" to find how many uses there are for oxygen other than in hospitals. Indeed, you will be surprised. Is commercial oxygen produced in quantity by the same methods Joan used? (No.) Children interested in chemistry might be challenged to find out how commercial oxygen is produced. Any investigations children might suggest doing to illustrate production of oxygen from chemical substances should be checked first by their teacher.

(*Text pages 232–233*)

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. a

Using What You Know. 1. Animals require the oxygen given off by green plants for the process of oxidation in their cells. Priestley's mouse became drowsy when it had used up some of the oxygen in the jar. 2. Bright day; green plants need sunlight for best production of oxygen.

(*Text pages 233–236*)

SUBCONCEPT

During photosynthesis, green plants manufacture simple sugars and starches, using the energy of light.

Processes emphasized

Investigation (with design of experiment)
Analysis of data
Hypothesizing
Theorizing
Prediction
Reporting (exhibit)

Section 2: THE IMPORTANCE OF LIGHT

Children develop greater understanding of the process of photosynthesis in green plants.

Introducing the Concept

Ask whether a plant really "lives" on Earth. Imply that perhaps it doesn't. The perceptive child may infer that the green plant lives in the solar system. It gets its energy from the Sun, 93,000,000 miles away. Recall that in building up compounds (Unit Two), elements were combined; and in breaking down a substance, elements were often released. Do animals build up and break down compounds? Children should recall, from Unit Five, that animal cells break down compounds such as carbohydrates, fats, and proteins and build up other compounds. Where do many of our food products come from? Can it be possible that plants also break down and build up compounds? Let us first look at the compounds plants build up.

Why are we so interested in photosynthesis? What word does the first part of *photosynthesis* remind you of? (Photography.) **On what kind of energy do both photosynthesis and photography depend?** (Light.) **Why do we call plants the food makers of the world?**

Developing the Concept

Green plants as energy traps. After the children have read the text of the section and have helped you set up the first part of the investigation on page 235, present this question for discussion: Why can we speak of green plants as energy traps? What does a plant cell need to be able to make oxygen? (Chloroplasts.) Can a mushroom make oxygen? (No; it has no chloroplasts.) What connection is there between chlorophyll and chloroplasts? (The greenish bodies in a plant cell are filled with the green coloring matter; *chloro-* means *green.*) What is the relationship between chlorophyll and photosynthesis? If possible children should have an opportunity to see green plant cells under the microscope. One of the best plants for this purpose may be in your aquarium. A slide of the torn edge of a leaf of *Anacharis,* one of the elodea group, shows clearly the green chloroplasts lining the cell walls. Children may wish to make drawings or models of what they see.

Green plants can directly trap and store the energy of sunlight.

Equipment and Materials

. . . *Anacharis* (from aquarium)
. . . microscope
. . . slides

(See text page 235; also the Teacher's Manual for *Classroom Laboratory 5.*)

What are the plant's energy traps? (Chloroplasts.) What kind of energy are they able to capture? (Sunlight.) How is the energy trapped? The answer may be elicited by correctly completing the statement: During photosynthesis green plants make (a) only starches, (b) only sugars, (c) first sugar, then starches, (d) a mixture of sugar and starches.

How do we know plants manufacture carbohydrates? The second part of the investigation on page 235, after sunlight has been withheld from leaves, offers an opportunity for children to relate techniques and methods of investigation. To understand the reasons for certain safety regulations, they also make use of earlier concepts in learning. Why is the alcohol not heated over an open flame? Children who recall the effect of heat on evaporation may be able to infer that alcohol changes from liquid to gas at a low temperature. What element in alcohol readily combines with oxygen? (Carbon.) How does the gaseous state increase the chance of rapid oxidation in the presence of a flame? (Molecules are farther apart, thus increasing the surface area.) Warming the alcohol speeds up the rate of dissolving of the chlorophyll from the leaf.

Light is essential for the manufacture of carbohydrates by cells in a green leaf.

What chemical test shows the part of the leaf that has made starch? (Iodine turns starchy areas bluish black.) How do we know that sunlight was necessary for manufacturing carbohydrates? (The part of the leaf that was covered does not test for starch.)

Garden in a grocery store. Do all plant cells store carbohydrates? Are only some cells specialized for carbohydrate storage? How could we find out? Encourage children to use the iodine test for starch upon a variety of foods. They may think first of those derived from grains. What about unprocessed or raw foods? They should discover for themselves that carbohydrates are stored in roots (carrots and the like), in tubers (potatoes), in stems (celery), and in other specialized plant tissues.

Children discover that many of our foods come from plant cells specialized for storage of carbohydrates.

Equipment and Materials

. . . iodine
. . . sample foods

To record and fix what they learn about food storage in plants, a small group of children may be encouraged to set up an exhibit entitled "Garden in the Grocery Store." For the background the children can draw and cut out colored paper to illustrate parts of a stylized plant—green for leaves, brown for stem, red for roots, etc. Collect empty containers or pictures of plant foods. Connect these with colored yarn to the appropriate part of the big "plant"; for example, artichoke hearts to the plant flower or fruit part. The children begin to realize that plant tissues which store food for the plant's use are often the parts we eat.

Extending the Concept

Equipment and Materials

- . . . wax paper or plastic sandwich bag
- . . . flat iron
- . . . newspaper

Why do leaves turn color in the fall? As autumn comes to the north, what happens to the green color? Do the chloroplasts disappear? If children have had an opportunity to examine green leaf cells under the microscope, they have learned how to recognize the chloroplasts which carry the green pigment in cells. Microscopic examination of multicolored fall leaves reveals chloroplasts still in the leaf cells. Seasonal changes in plant cells are triggered by the changing amount of daylight. These changes result in a decrease of green chlorophyll and unmask red, yellow, and orange pigments.

A rough analogy might be illustrated by a method used frequently in children's art. Children coat a drawing with layers of different colored crayons. The underlying pigments are revealed only when the child uses a sharp tool to etch out his design.

If autumn comes to your part of the world with a brilliant splash of colored foliage, you and your children may long to preserve their beauty. If autumn has passed, these directions may be useful for another year. Set small tree branches into a solution of glycerine and water. The leaves remain soft and pliable and the color is also retained.

Another way to preserve colored leaves is to coat them with paraffin. Use a slow, low-heat iron to press colored leaves inside a plastic sandwich bag or between two sheets of wax paper. While ironing, use newspaper above and below the wax paper to absorb excess wax.

(*Text page 236*)

Reviewing the Concept

Before You Go On. A. 1. b 2. b 3. a 4. b

Using What You Know. 1. Make its own food. 2. In spite of its ability to move freely, scientists usually classify Euglena as a plant.

(*Text pages 237–241*)

SUBCONCEPT

Green plants make carbohydrates from carbon dioxide and water; animals are dependent on green plants for their food.

Section 3: THE LONELY GREEN PLANT

Children begin to appreciate photosynthesis as a chemical process crucial to the existence of all living things.

Introducing the Concept

Can you name the two products made by the cells in a green leaf? (Oxygen, carbohydrates.) What two elements does the word *carbohydrate* make you think of? (Carbon, hydrogen.) Oxygen, carbon, and hydrogen are three building blocks in the carbohydrate compound. From what you learned in Unit Two about the building up and breaking down of substances, would you conclude that oxygen, coming from the plant, also was brought into the plant to build up the compound? Or would you conclude that oxygen leaving the plant came from the breaking down of some compound?

Processes emphasized

Investigation (with design of experiment)
Analysis of data
Model making
Prediction
Hypothesizing
Theorizing
Library research

Consider the difference in the size and weight of a tree seedling and a large tree. Where did the size and weight of the tree come from? Did the materials that make up the tree just come from thin air? Is it ever possible to get something from nothing?

Where does the green leaf food factory get its raw materials? How important are plants to all living things?

Developing the Concept

Reasoning from evidence and observation. Before the children read their text (up to "The Independent Green Plant"), encourage them to think about the sources of the building blocks of carbohydrates. Where do plants grow? (In air, soil, and water.) What is a common compound found everywhere that contains carbon? (Carbon dioxide.) What is the most common compound that contains hydrogen? (Water.) Can either supply oxygen? (Yes.) Recall with students the earlier concept that in a chemical reaction, matter is neither gained nor lost. Could it be that the plant gives off oxygen because there are more oxygen atoms than it needs to make a carbohydrate molecule? Encourage the children to express in a word equation the idea that from carbon dioxide and water a green plant makes carbohydrates and gives off oxygen. Children can now check their reasoning by reading the first part of the section.

Children infer the sources of the carbon, oxygen, and hydrogen a green plant uses in photosynthesis.

Sealing-in an organism. The investigation suggested (text page 239) should be planned early in the development of the section. Aquarium hobbyists within the class or community may be of assistance.

Children gain further insight into the interdependence of organisms and their environments.

Some children may wish to test directions given for light and temperature. Compare results with jars set in darkness, in a cold place, and in a warm place. Encourage them also to test their aquarium water for protozoans and other microscopic organisms. Do they live, too, when they are sealed in with the plant? Will light and temperature affect them? From what you now know about how plants and animals break down and build up compounds, can you explain why both plants and animals stay alive sealed in a jar? (Animals need oxygen; plants need the carbon dioxide animals produce.)

Do plants make only carbohydrates from carbon, oxygen, and hydrogen? From your work in Unit Five, can you mention one other compound of these three elements? (Fat.) Do plants make fats? Peanuts are mentioned in the text. Encourage children to check their home pantry shelves for evidence of plant fats. Among them are likely to be oleomargarine, salad oils, shortening, and various nut products.

Plants make and store fats.

Plants make and store proteins.

Equipment and Materials

- . . . clover or pea plant, or other legume
- . . . microscope
- . . . slides
- . . . iodine

How do plants make proteins? What element is in proteins that is not in carbohydrates and fats? Children should recall the answer (nitrogen) from their work in Unit Five. Would the plant get nitrogen from the air? In Unit Two children learned that nitrogen is quite inactive chemically; they should deduce a negative answer. Now hold up a legume, roots and all, from which you have washed the soil. This plant did capture nitrogen; these tiny swellings on the roots contain a special kind of bacteria that are able to make a compound that the legume can use to "fix" (catch and change) nitrogen from air in the soil. In fixing nitrogen, they make nitrates (compounds of nitrogen and hydrogen) which will dissolve in water. Commercial fertilizers contain nitrates which will dissolve in soil water and be able to pass through plant cell membranes. If the nodules on the roots are large, you can see a reddish cast due to hemoglobin, the same iron compound found in the blood, which aids in nitrogen fixing.

If you have time to extend the concept, crush a nodule between two glass slides and add a drop of water to make a wet mount for better microscopic study. Under high power the children can see the bacteria. These transparent organisms may be seen more easily if stained with iodine or ink.

Children continue to associate science with evidence and reasoning.

Reasoning and evidence. It may also be useful to invite a discussion of the terms *reasoning* and *evidence*. Encourage examples of each. Give examples of thinking and behavior not based upon reasoned evidence. Which kind of thinking and behavior is more useful? Why? Can you now see a relationship between hypotheses and the reasoning-evidence team? *Educated* guesses should be inferred only from reasoned evidence. Wild guesses usually stem from thinking based on little or no evidence. Can you think of examples?

Extending the Concept

Equipment and Materials

- . . . plastic containers for collecting
- . . . wide-mouthed gallon pickle or mayonnaise jars
- . . . drinking-straw pipettes

Never one without the other. If possible, collect some slow-moving or stagnant water from a swamp, pond, or stream. Usually you will also scoop up some fresh-water algae or higher plant forms. Your sample probably will contain a fascinating circus of fresh-water insects and other animal forms. Use drinking-straw pipettes to draw up samples of water from the bottom life in your fresh-water aquarium jar. Usually it will be found to contain microscopic plants and animals. The children by now should be able to explain why plants and animals are usually found living together. Models or diagrams to illustrate the carbon-dioxide–oxygen cycle in a fresh-water aquarium could deepen the children's understanding. For further help in keeping and studying water life, see pages 46–61, *A Sourcebook for Elementary Science.*

What substances does a willow tree need? Whenever possible, it is desirable to expose children to original source material. Depending upon the reading level of your group or of individual children, you may wish either to read aloud or duplicate the historical account of van Helmont's experiment quoted on page 25 of *A Sourcebook for the Biological Sciences.*

The seven questions which follow the quotation may be modified as you wish.

Do plant factories always produce at the same rate? If you needed to depend on plants for food, would you settle in cold highlands or warm lowlands? (The latter.) Which kind of environment offers the richer source of raw materials—thin upland or mountain soil, or deep lowland soils? What relationships can you see here between science and geography? Why do people settle and live where they do—the world over?

Reviewing the Concept

(Text page 241)

Before You Go On. A. 1. b 2. b 3. a 4. a 5. a

Using What You Know. Water plants; because they will add to water the oxygen that the fish needs to stay alive.

Section 4: WE SEAL IN A FISH—AND A COW

(Text pages 242–246)

SUBCONCEPT

Living things obtain from one another and from the environment the matter and energy they need for growth and activity.

Children reason from the evidence of living things thriving in a sealed environment that all living things are dependent on the matter in their environment; all living things are "sealed" into the environment of planet Earth.

Processes emphasized

Observation
Investigation (with development of models)
Hypothesizing
Theorizing
Inference
Prediction
Analysis of reading

Equipment and Materials

. . . sealed jar used in Section 3
. . . water snails

Introducing the Concept

What do we mean by the term *environment?* For proper conceptualization of the relationship of living things in a sealed environment, it may be desirable to do a bit of preliminary exploration of the children's present understanding that environment consists of all the matter and living things surrounding an organism, as well as conditions favorable to life. What does your environment consist of? What would be missing in Antarctica? What would life be like on a desert? What is a poor environment? (One that does not sufficiently supply the needs of an organism.) What is a good environment?

In Section 3, you found that plants and microorganisms could live in a sealed world. What was in their environment that they needed to stay alive? What if we add a snail to one of the jars? Will the snail live? Would a fish? Will the plants keep on living?

A water snail may be added to one of the jars; then children can check their predictions by reading the text of the section.

Developing the Concept

Children come to realize that animals and plants in a sealed environment depend upon one another; the oxygen—carbon-dioxide cycle is essential in their environment.

What kind of an environment does an animal need? What does a water snail or a fish need to live sealed in a jar? (Oxygen, food.) Why? (An animal cannot make its own food; it has to have oxygen for its cell energy process.) Where does the oxygen in a sealed jar come from? (The plants.) What kinds of food do the animals get from the plants? (Carbohydrates, fats, proteins.) What else do plants supply? (Minerals.) In review, encourage children to tell how plants make food and describe the cell energy process in animals. What is the oxygen–carbon-dioxide cycle? As children cite special needs of an organism, you may wish to write them on strips of tag board for a summarizing activity at the end of the section.

An organism must have an environment that supplies its needs in adequate amounts.

How much environment? Would a large fish or a dozen snails live in the environment of the jar? (No.) Encourage close attention to detail in the reading. Are any of the needs lacking in the environment? (No.) What counts then? (Enough of the needs; that is, the environment must supply what the organism needs.) Encourage creative ideas in making models of a sealed-in environment for different kinds of living things. For example, a frog, robin, dog, tree. Has everything the animal needs been included? What one need from environment must all animals have? (Green plants.) The interdependence of organisms with their environment can be reinforced by asking children to look for omissions in one another's models.

Equipment and Materials

. . . cellophane or plastic covers
. . . toy animals
. . . tags

Each kind of organism is adapted to a special environment.

What kind of environment? Is the environment of a fish the same as that of a cow? What differences are there? Is the environment for a palm tree the same as for a maple? Is the environment for a cactus the same as for a willow? What differences are there? Are they all sealed into their environment? Although adaptation is not discussed in the textbook at this point, it is implied and can be developed by inference.

The environment to which an organism is adapted supplies all the organism's needs.

Plant and animal needs. If you have made strips of tag board listing the needs of plants and animals—food, water, oxygen, carbon dioxide, temperature, etc.—you may now wish to bring together the ideas of the section for a quick review. Place pictures or cutout drawings of a plant and an animal on opposite sides of a bulletin board or flannel board. Ask the children to pin or place the word cards between, in what they believe is appropriate order, first for the plant and then for the animal. Is there a change in the order of the cards? Why? (Hint: Do plants make food? Do animals? How are their needs different?)

Equipment and Materials

. . . test tubes
. . . water snails
. . . water plants
. . . corks
. . . sealing tape

Each child, or each group of children, may make a test-tube world for one snail. Each must justify choice and quantity of materials, and the place they select to keep the tubes. The tubes should then be corked, sealed with tape, and observed for several days or weeks. Were all the snail's needs met?

Draw a passing analogy to the "closed system" of the astronaut in his space capsule.

Extending the Concept

What is a "closed system"? Encourage children interested in space or oceanography to draw parallels between the sealed-in fish and survival in a space capsule or submarine. Why do we say each one is an example of a "closed system"? A panel of children who have investigated the subject might stimulate a debate on the two sides of the statement: "We are sealed into our Earth environment."

Relating the concepts to reading and social studies. Some children might enjoy locating pictures of geodesic domes or constructing Tinkertoy models. The designer envisions that such structures will permit man to live and work in such hostile environments as the Antarctic or the Moon.

Examples of environmental relationships from social studies lessons could be integrated here. Field trips can locate nearby and everyday examples, e.g., land snails in a damp, leafy environment; succulents and cacti flourishing in a hot, dry, sandy environment; pigeons, pets, and English sparrows in a city environment.

Reviewing the Concept

(*Text pages 245–246*)

Before You Go On. A. **1.** a **2.** a **3.** a **4.** a

Using What You Know. When a plant oxidizes carbohydrates, carbon dioxide is given off. A fish gives off carbon dioxide that the plants can take in for photosynthesis.

Section 5: THE GREEN PLANTS THAT SAVED THE LIMEYS

(*Text pages 246–248*)

SUBCONCEPT
Green plants are a basic source for many substances needed by all animal life.

Processes emphasized
Observation
Analysis and application of data
Consulting "experts"
Library research
Inference

Children are introduced to the importance and variety of vitamins produced by green plants.

Introducing the Concept

Why is orange juice good for you? What if you never drank any orange juice? Could you starve to death in a candy factory? A pastry shop? An ice cream parlor? Why?

A discussion of these questions should provide an inventory of what children know about eating a variety of foods. Suggest to the children that they bring in food packages, such as cereal boxes, bread wrappers, milk cartons, and any other containers that state the food content. Which of them mention vitamins?

How could you starve on three meals a day?

Developing the Concept

Plants are a source of food substances that keep us well.

What are vitamins? After children have read the section in their textbook, develop understanding of the evidence showing that green plants build not only carbohydrates, fats, and proteins, but a fourth kind of substance that keeps us well. How did Dr. Lind find his problem? How do you think he stated it? How did he plan his investigation? What was his control? Do you think his methods were like Joan Waterman's? Were they different in any way? What did he conclude?

What did you eat today that makes you a limey? Your list of ways in which we depend on plants keeps growing. What plant substance can you now add to the list?

Certain diseases are avoided or cured by adequate amounts of vitamins.

Vitamin deficiency and its cure. Your textbook mentions scurvy, beriberi, nightblindness, and rickets as conditions that are caused by lack of certain vitamins. These are usually called *vitamin deficiency diseases.* How many vitamins does your textbook mention? (Four—A, B, C, D.) These are among the most important, although there are others. What food must we eat to get the necessary vitamins? Using your textbook, can you complete a chart under three headings like the following:

Vitamin	**Food Sources**	**Condition Prevented**
A	Cod liver	colds, dry skin

Children infer the importance of having a balanced diet every day.

What foods should everyone eat each day? What makes a good breakfast? Do you think an ice cream soda and a candy bar have the vitamins you need for a good lunch? What makes a good dinner? Encourage children to reason that carbohydrates, fats, proteins, and four kinds of vitamins are desirable each day. As children design a menu for each meal, the teacher should be sensitive to children's cultural food patterns and habits rooted in economic conditions. The meals can be developed as objective ideals for everyone to try to meet in his own way.

Extending the Concept

Could you starve on three meals a day? What did Dr. Lind discover? (Sailors were starving because of lack of vitamin C.) The sailors ate mainly dried meat and hard biscuits. Do you think they got enough of vitamins B and D? Why? (No green vegetables on board ship.) Health textbooks or science books having sections on food and nutrition often have illustrative charts and pictures of the U.S. Department of Agriculture Basic Four food groups:

Milk Group. Milk and milk products, such as butter, cheese, ice cream.
Meat Group. Meats, fish, and—as substitutes—eggs, dried beans and peas, peanut butter, nuts.
Bread–Cereal Group. Breads and whole grain or enriched cereals.
Vegetable–Fruit Group. Green and yellow vegetables (cooked, frozen, or raw), salad greens, tomatoes, root vegetables, all kinds of fruits.

Children may be encouraged to reproduce the Basic Four chart and attach pictures or drawings to it.

Using local personnel. School health and nutrition personnel from the school cafeteria may be invited to explain how school lunches are planned and how foods are selected and obtained. Possibly they might encourage children to participate in menu planning as an extension of their science work. Art personnel may assist in planning display posters of good menus.

The school doctor or nurse may be enlisted to discuss vitamins. In any event, it is desirable to direct attention to the desirability of choosing foods to obtain adequate vitamins rather than to the use of vitamin pills. Few children need supplementary vitamins except on a doctor's prescription.

Reviewing the Concept

(*Text page 248*)

Before You Go On. A. 1. a 2. a 3. a 4. b

Using What You Know. 1. Vitamin C. 2. Carrots contain vitamin A which may be needed to correct the condition.

Section 6: ARE YOU SEALED IN?

(*Text pages 248–251*)

SUBCONCEPT

Man, like all other living things, is dependent on his environment—on all the matter and living things in it.

Processes emphasized

Observation
Inference
Hypothesizing
Theorizing
Model making
Reading and reporting

Equipment and Materials

. . . snail or insect
. . . saucer of water
. . . plastic bag

Children realize that they are as much "sealed" into their Earth environment as the fish or snail that they "sealed" into a jar or test-tube environment.

Introducing the Concept

You might put a snail or an insect upon a potted plant. Set the pot in a saucer of water. Enclose all in a plastic bag and close securely.

In sunshine, moisture should condense inside the bag, a crude analogy to the evaporation-condensation cycle in Earth's atmosphere.

What is there in the snail's environment which is also in yours? In the cow's? What essential parts of your environment must you take with you if you leave the land environment in a jet, submarine, or space capsule?

It should become clear to the children that the traveler must carry food, oxygen, and water—all essential needs to remain alive in the special environment of these means of travel.

Recall with the children that foods contain carbohydrates, fats, proteins, water. What elements are needed to make these foods? (H and O in water; C, H, and O in fats and carbohydrates; C, H, O, and N in proteins, and sometimes phosphorus and calcium.) What element makes up a large part of your bones? (Calcium.) Calcium and phosphorus are minerals.

Where do we get our minerals? Perhaps you have a dog as a pet. What does it eat? Can you trace its food back to a green plant? This is like a chain, isn't it? In fact, it is often called a food chain. Can you trace your food back to a green plant? What kinds of food chains are there?

Children now read the section to develop more fully the ideas in the introductory inventory questions.

Developing the Concept

Children realize the need for foods rich in certain substances.

Do we need iron? If you run a magnet over your arm, can you find any iron in it? (No.) Is there iron in your body? Elicit recall that hemoglobin is a compound in red blood cells that is rich in iron. Why do we eat spinach, red meat, and liver? (Iron compounds.) How does the iron get into spinach? Into meat? (From the soil through plants' roots and into meat when the animals eat the plants.) Can you reason what might happen if we did not get enough iron? (Red blood cells would not pick up enough oxygen; food would not be oxidized; we would not have energy.) Anemia is a disease characterized by lack of iron or inability of the blood cells to pick up oxygen.

Children infer the nutritional values of food substances in milk.

Why do we drink milk? Milk is often called a complete food. Why do you think so? What do the carbohydrates and fats give you? (Energy.) The proteins? (Materials for growth—more cells, more tissues, such as muscles.) What mineral does milk particularly contain? (Calcium.) Can you give reasons why milk is the first food for babies? What is the particularly important job of vitamin D in milk? (Enables body cells to use calcium.) How does calcium get into milk? By now, children should readily trace the substances in milk to the food the cow eats.

An understanding of the concept of interdependence of organisms upon one another and upon the environment is reinforced.

Food chains. Cutout paper loops or a section of chain can represent chain links. In the chalkboard tray, set pictures of animals that are dependent for their food upon other animals. Challenge children to attach the pictures in order in the spaces between the links; for example, mouse–snake–heron–fox. What two things are missing? (Plant, and the Sun as source of energy.) Although the text does not develop the return of matter to the soil and atmosphere as an organism dies and decays, children may infer that this event completes the chain, or life cycle. If they understand the Sun as the source of energy for the cycle, they may wish to place it at the center of the complete linking of the chain.

Extending the Concept

Environment for air and space travel. Encourage children with special interest in space to investigate some of the problems of feeding the astronauts. A report should include problems of making or carrying food and other elements of the environment in a space capsule. You may also be able to arrange a class visit by a stewardess or other airline representative to demonstrate and discuss use of oxygen masks and other problems involved in flying seven miles above the Earth.

A whale's dinner. What does a whale have for dinner? Encourage children interested in ocean life to report on plankton, the minute types of organisms that provide a basic link in food chains of the sea. What is plankton? How does plankton look? What does it feed on?

(*Text page 251*)

Reviewing the Concept

Before You Go On. A. **1.** a **2.** b **3.** a **4.** b **5.** a **6.** a **7.** a

(*Text pages 252–256*)

SUBCONCEPT

Interdependence of living things with their environment is related to the transformation of matter in a chemical change.

Section 7: CELLS THAT BUILT OUR FUEL SUPPLIES

Children extend the concept of interdependence backward in time and discover, that, though living things were much different millions of years ago, animal life depended on green plants for the capture and storage of energy from the Sun.

Note. This section provides an opportunity to extend the concept of this unit by review of concepts in other units. Indirectly—or directly—you are thus able to bring out the unity in science that helps give meaning to the diversity visible within our environment.

Introducing the Concept

Can you burn stored sunlight? After a brief exploration of the question, display a chunk of coal and a can of oil and two labels "Canned Sunshine" and "X Million Years Old." Which label should we put with the coal? Which with the oil? If children do not recall that coal is the fossilized remains of green plants, hold the question in abeyance until they have read the text. Or: could we have coal today if there had been no plants millions of years ago? (No.) How about oil?

Why are coal and oil called fossil fuels? How was their energy stored? What chemical reaction releases their energy?

Processes emphasized

Observation and analysis
Field trip
Prediction
Hypothesizing and theorizing
Model making

Equipment and Materials

. . . chunk of coal
. . . can of oil

Developing the Concept

Oil from the Earth. In 1859, Edwin Drake was drilling a well for water near Pittsburgh, Pennsylvania. Oil seeped up and filled the hole after he had drilled 69 feet. How did this oil get there? From your reading, you know that it came from microscopic organisms that lived in the seas many millions of years ago. But how did it get into the rock high above the bottom of the sea? Refer children to their work in Unit One. Encourage use of the index to review sedimentation, folding, and faulting of rock layers. Now can you suggest how oil gathered under domes of rock? Why is oil trapped there? A rapid investigation should lead to an inference. Let children place a drop or two of oil on a bit of sandstone, marble, and granite (or use sand and glazed tile). Which absorbed the oil? (Sedimentary rock—or porous substance.) Why are drillers especially interested in sand layers in drilling oil wells?

Children review earlier concepts to relate oil deposits to sedimentation in ancient times.

Equipment and Materials

. . . sedimentary rocks
. . . metamorphic rocks
. . . igneous rocks
. . . oil

Can you trace the source of the stored energy in oil back from the organisms that made it? Could you say that the Sun's energy stored in these organisms runs a car or heats a house? (Yes.) What chemical process is involved? (Oxidation.)

Carbon in the Earth. Review fossils from Unit One. How do we know that coal is a fossil plant? (Leaf prints in some pieces.) How did these "fossils" capture and store energy? (Photosynthesis.) How did coal become buried so deep in the Earth? (Sedimentation, uplift, folding, faulting, as in Unit One.) Do you see a relationship between the big idea that the Earth is in continual change (Unit One) and the interdependence of living things (this unit)? The child's text mentions the huge dragonflies and other giant animals of the coal forests. How does this picture of ancient life suggest interdependence of plants and animals? (Animals had to have the green plants to provide stores of energy for their life.) How are ancient environments an aid to our own life? (We use the stored energy of the Sun captured millions of years ago.)

Ways of life today are related to the interdependence of organisms that lived in an ancient environment.

natural plant fibers used in clothing; e.g., linen, flax, grasses, and copra. The labels on clothing often indicate a combination of plant or animal fibers with synthetic products. These labels may be displayed with fabric samples; stress the natural fibers at this point rather than the synthetic nylon, rayon, Acrylon, Dacron, or other man-made fibers.

Extending the Concept

The first papermakers. If black-faced hornets build nests in your area, encourage discreet collection and examination of an abandoned nest. First make sure the nest is no longer in use. The same is true for a nest brought indoors in winter. The warmth of the room may rouse the torpid inhabitants to unwelcome activity! The trouble of finding a nest for examination is well rewarded by a close look at the beautiful colors and patterns of wood fibers which coat the nest. If cautious direct observation is not possible, imagine the first papermakers, the hornets, at work. They may have gathered wood fibers from a silver-grey, weathered fence post and reduced them to pulp by their strong jaws. They then spread the pulp out ribbonlike to dry, layer after layer, much as a ball of string grows, until the nest was formed. Such a work of skill and beauty is well worth close examination.

Commercial paper making. Collect samples of paper for a bulletin board exhibit. Microscopic examination and description by a committee can extend understanding of fibers obtained from green plants and processed by man. Inquiry to paper manufacturers will yield added information. Arranging a committee or class field trip to a neighborhood paper mill is recommended. In preparation, children should read all available information on how paper is made.

Equipment and Materials

. . . silkworm
. . . mulberry leaves

The story of a piece of silk. The story of silk is enmeshed with history and geography as well as with science. An understanding of how silk fibers are obtained can be greatly enriched by raising silkworms and watching them spin their cocoons. The live cocoons must be boiled to kill the larvae before children start to pick out the end of the silk thread from which the cocoon is woven. Raising silkworms is best carried out in spring as mulberry leaves begin to emerge. (For further details, see page 78, *A Sourcebook for Elementary Science* and *Silkworms and Science* by Elizabeth K. Cooper, Harcourt, Brace & World, 1961.)

Synthetic fibers. Today, many items of clothing no longer depend directly on green plants to make cellulose or on animals to make fibers as they build protein molecules. Interested students may investigate, through reading in references, how nylon, rayon, Dacron, Acrylon, Lanital, and other synthetic fibers are made. For example, they will discover that some are made from cellulose or coal-tar products. In their report, encourage them to trace the synthetic product to a green plant if they can. Man, through chemistry, has often rearranged the atoms in molecules to obtain fibers with the desired properties.

(*Text page 260*)

Reviewing the Concept

Before You Go On. A. 1. b 2. a 3. a 4. a

Using What You Know. 1. Glass, a man-made product. 2. The man in the wool coat; the cotton fibers would have been plant cells with cellulose.

(*Text pages 261–264*)

Section 9: THE MAIN CONCEPT: THE SUN'S ENERGY CAPTURED

CONCEPTUAL SCHEME
Living things are interdependent with one another and with their environment.

UNIT CONCEPT
The capture of radiant energy by green plants is basic to the growth and maintenance of all living things.

Children review the work of green plants in the production of oxygen; of fats, proteins, and carbohydrates; of vitamins; of fossil fuels; and of fibers for clothing. In so doing, they strengthen their understanding of the conceptual scheme that living things are interdependent with one another and with their environment. They see more clearly that the capture of the energy in sunlight is basic to the maintenance and growth of all living things.

The text of the section is brief. However, there are many ideas brought together and summarized. Encourage thoughtful reading as you develop the concept summary.

CONCEPT SUMMARY

How do green plants capture energy from the Sun?

A weed, a geranium, and a tree. What one activity do these green plants all engage in every sunny day that scientists have so far failed to accomplish? (Trap the energy of the Sun.) What change do green plants make in the energy they capture? (Change it into stored chemical energy.) Why do we say the energy is stored? (It can be used as food or as fuel; that is, the energy stored can be changed by oxidation into another form of energy.) Compare a piece of coal and a stone, for example. Can you burn a stone?

What is the most important chemical reaction on Earth?

A chemical equation. What two forms of matter does a green plant chiefly use in making food? (Water and carbon dioxide.) Green plant cells take matter and energy from the environment and store them in a different form. What is the process? (Photosynthesis.) Can you write the equation which describes the change of sunlight energy, carbon dioxide, and water into the stored chemical energy of food? It has been said that this equation describes the most important chemical reaction in the world. Would you agree or disagree? What evidence can you give to support your opinion?

How is the environment important to all living things?

Are sunlight, water, and carbon dioxide enough? Suppose there is little rainfall for several years, as has happened in Texas and the western plains states, the so-called Dust Bowl. Or that the temperature drops to 20° F. in a region that produces oranges and grapefruit. Can the plants make and store food as they normally do? What happens to farm and wild animals? What happens to man? What do we call the surroundings of plants and animals? (The environment.) Can you name other illustrations of changes

The stored energy of the Sun is transformed into other kinds of energy; man's environment depends on the past as well as on the present.

The energy of sunlight. Challenge children to name a form of energy that does not come from the Sun. Could plants make food without the Sun? Could animals "go and grow" without the Sun? Could man—you—run an automobile or factory without the Sun? Be sure children think of the past storage of energy as well as present processes of energy storage. Into what kinds of energy is the energy of sunlight changed in green plants? (Stored chemical energy.) The energy in oils? (Mechanical, heat energy.) In coal? (Mechanical, heat energy.) In foods? (Muscular energy, a form of mechanical energy.) Some other answers are justifiable, also.

Equipment and Materials

- . . . shoe box
- . . . modeling clay or magazine illustrations
- . . . cellophane
- . . . living organisms
- . . . glass panes
- . . . adhesive tape
- . . . roll of shelf paper

Extending the Concept

Making a fossil fuel diorama. Some children may wish to investigate further either or both of the fossil fuels. They might be encouraged to construct "shoe box" dioramas showing with modeling clay or magazine illustrations the plants and animals living together in the coal-age landscape. A model greenhouse of cellophane might contain ferns, salamanders, etc. With glass from window panes and tape the children can build a terrarium and plant it to suggest a miniature carboniferous landscape.

From living cell to carburetor. With shelf paper, children of an artistic bent may devise a "filmstrip" sequence covering two billion years or so, showing how marine organisms captured sunlight energy, stored it, were subjected to changes in the Earth's crust, were finally uncovered in the twentieth century, and powered a summer vacation automobile trip. Ingenuity and artistic ability should, of course, be checked against comprehension of (1) interdependence, (2) the continued, but sometimes slow, changes in the Earth's crust, and (3) the transformation of matter through chemical change. Other children may prefer to develop a filmstrip sequence covering 250 million years or so, from the giant ferns of the coal ages to the smelting of steel in a blast furnace. Children's encyclopedias are useful references.

(*Text pages 255–256*)

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. a

Using What You Know. 1. Coal was formed by green plants. 2. a. Calcium carbonate. b. Shells of single-celled animals. 3. Carbon dioxide and water. Under pressure and heat, oxygen was driven off, leaving a compound of hydrogen and carbon.

(*Text pages 257–260*)

SUBCONCEPT

Plant and animal cells change matter as they interchange matter and energy with the environment.

Section 8: CELLS THAT MAKE CLOTHING

Children extend their concept of the work of cells. In addition to storing energy, plant cells build cellulose. Animal cells release energy and build proteins. Cellulose and certain fiberlike proteins in animal hair are the source of fibers useful to man.

Introducing the Concept

Look around you. What do you see that has been built directly from plant cells? (Wood furniture, floors, doors, and other woodwork.) Listing of the products on the chalkboard can catalyze thinking about other products not so directly identifiable. How about our notebooks, textbooks, and other supplies? Are they all made from the substance in plant cell walls? What do you wear every day that comes from plants? (Items of clothing.) What do you wear that comes from animals? How can you be sure where it comes from? Could you have clothing from animal cells without plant cells?

The cells of the green plant are the most important cells of the world. What reasons justify this statement? (Green plant cells store the energy of sunlight; they change matter in the environment into other forms; they are at the base of the interdependence of all living things.)

Processes emphasized

Observation
Analysis of data
Investigation (with testing)
Inference
Hypothesizing
Theorizing
Prediction

Developing the Concept

Wool or cotton? Before the class begins, tease out fibers from a wad of cotton and from a woolen garment you are ready to discard. Which comes from a plant and which from an animal? How can we tell? Can we be sure from the sample of cloth from which they were taken? At this point, children should work in groups to carry out the investigations on text pages 258 and 259. After the investigation is completed, ask: Which cells contained cellulose? (Cotton.) Which an animal protein? (Wool.) If a microscope is available, examine cotton and wool fibers under low power and describe the differences noted. On the basis of the investigation, what do you note? (The animal fibers have a smell like ammonia; the plant fibers do not.) Ammonia contains nitrogen. You may wish to make a diluted solution of household ammonia for the children's comparison of odors. Animal protein and ammonia both contain the element nitrogen. Does the burning cotton fiber smell of ammonia? (No.) What element is lacking in the plant fiber, cotton? (Nitrogen.) Children should make the inference that plant fibers can be distinguished from animal fibers by burning, a chemical test.

Children evaluate the usefulness of plant and animal fibers.

Equipment and Materials

. . . fibers of cotton
. . . fibers of wool
. . . microscope
. . . household ammonia

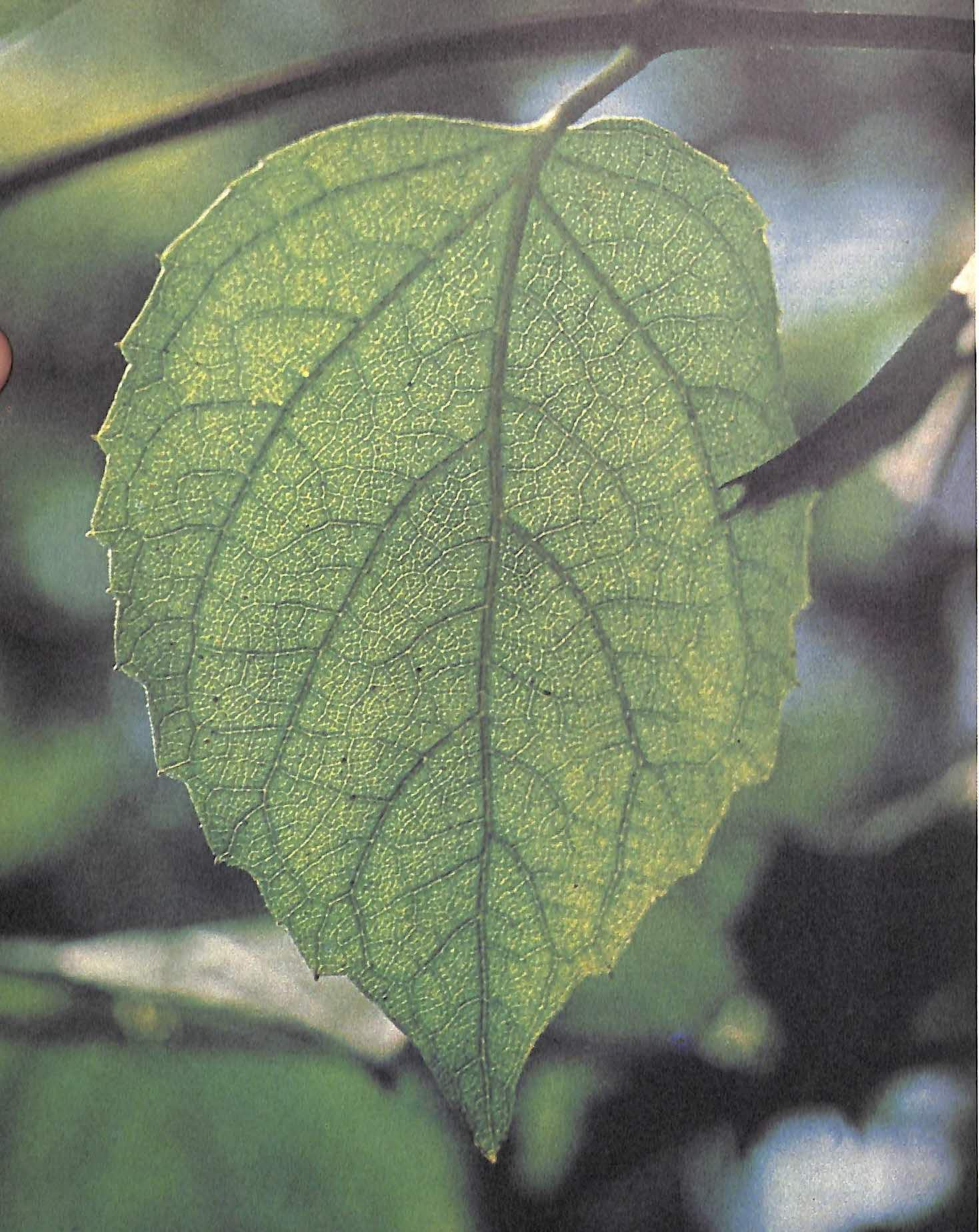
(See also text pages 258–259 and the Teacher's Manual for *Classroom Laboratory* 5.)

Interdependence. Can you have wool fibers without a green plant? Although the child's textbook does not develop the relationship, the perceptive child should be able to reason that carbohydrates and other plant products are eaten by the animal and changed by their cells into fibers such as hair and wool. Somehow nitrogen is built into the product. The text states that silk is made by the silkworm. What does the silkworm eat? (Plant cells—actually mulberry leaves.) Could you have silk without green plants? (No.)

Children reason from prior work that animal fibers are dependent on earlier capture of energy by green plants.

Display of plant and animal fibers. Encourage children to collect and display samples of different kinds, not patterns, of cotton cloth. Encourage use of the microscope. Children can see the close-knit threads of cellulose in fine percale, for example, and the loose weave of cotton sheeting. Cotton is a natural source of pure cellulose. Stimulate thinking about other

Plants and animals are useful to man in many ways.



UNIT SIX

GREEN CELLS AS BUILDING BLOCKS

Have you ever watched a builder putting up a house? He uses bricks, pieces of wood, panes of glass, and other materials, as building blocks which go together to make a house.

In one way, molecules may be thought of as building blocks. Molecules are the building blocks of cells. From the moment that you are born, your body takes in molecules from the air, water, and land around you. It uses these molecules to build more of you—to build more cells.

There is a special kind of cell without which life could not go on. You could not live without it. Yet this kind of cell is not in your body. It is not in the body of any animal. This kind of cell, you may be surprised to learn, is found only in green plants.

1. Joan Investigates

Joan Waterman, a high school student, was a lively girl and interested in many things. She played a good game of tennis and enjoyed playing the piano. But her hobby was keeping tropical fish. She had an aquarium at home with different kinds of fish and water plants in it, and often watched the graceful and colorful fish. See the picture marked with a square.■

One day Joan noticed something that made her wonder. Bubbles were rising from some water plants.●

Joan remembered something she had read about water plants—that they gave off oxygen. She hadn't paid much attention to it. Were these bubbles filled with oxygen gas?

Joan wondered. How could she find out if those bubbles really were oxygen? She thought of other questions, too. How much of this gas did a green plant make? Did the plant make gas all the time?

Joan went to the library to find out if anyone had tried to answer these questions. (She was doing what scientists usually do when they start an investigation: they read what has been done so far.) Sure enough, in a book on the study of plants, she found what she wanted.

Joan's Investigation

With her teacher's help, Joan got together the materials she needed and set them up.▲ She put some water plants and pond water in an aquarium. Then she mounted a funnel just above the plants with its mouth under the water. The funnel would collect any bubbles from the plants. Next, Joan filled a test tube to its top with pond water, and slipped it over the funnel so carefully that not one bubble of air got into the test tube. It was hard to do at first, but Joan soon got to be good at it. Now any bubble of gas from the plants would rise through the funnel into the test tube, and be caught. Everything was ready.

Joan placed the aquarium in sunlight. The plants began to give off gas. Bubbles rose into the test tube. At the end of the day about an inch of gas had collected at the top of the tube.

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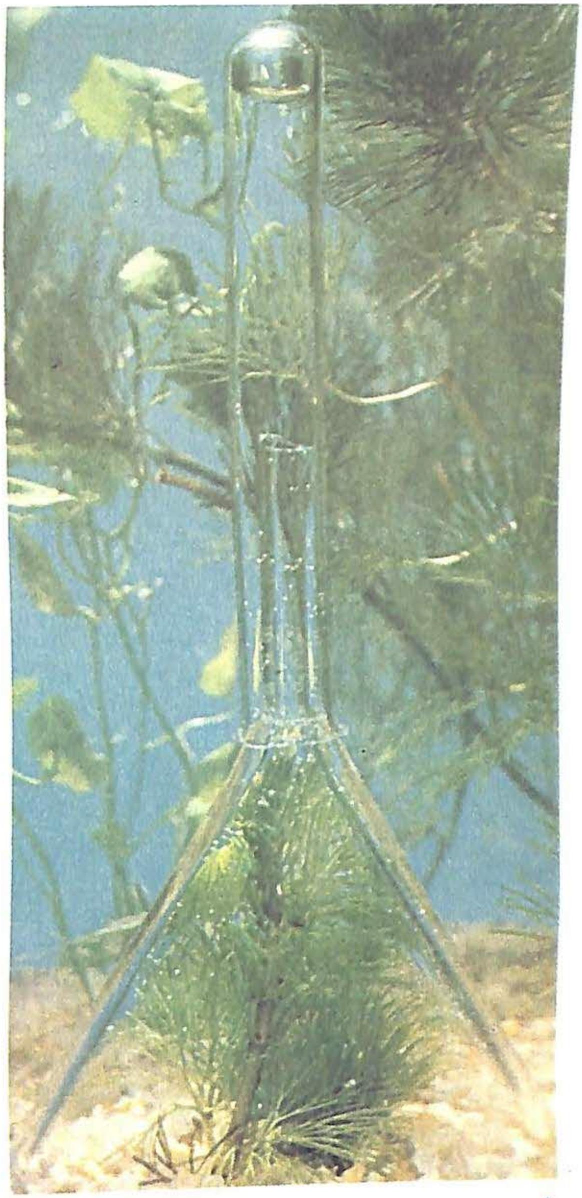


▲

However, to test the gas properly, more gas was needed. Joan kept the investigation going for a week and a half. At the end of that time the test tube was full of gas. Not every day had been a sunny one. Joan had noticed that more gas was collected on a sunny day than on a dull day.

from it. The oxygen helped give the mouse energy. Each time the mouse breathed out, it gave up carbon dioxide and water. So as the mouse breathed, the air in the jar held less oxygen—and more carbon dioxide. Can you see why the mouse became drowsy?

Then Priestley put a green plant under the jar with the mouse. In a while the mouse was lively and scampering about again. Joseph Priestley saw that the air in the jar had become "good air" again. But he was not sure why.

Can you explain why Priestley's mouse became lively again after the green plant was put in the jar? The green plant was giving off oxygen, as green plants do. Oxygen was just what the mouse needed. It had become drowsy because there was too little oxygen and too much carbon dioxide in the jar.

Green plants, in light, give off oxygen.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Joan learned about a gas that green plants give off. She learned by
   a. investigating and reading
   b. investigating only
   c. reading only

2. Joan's green plants gave off this gas in
   a. sunlight
   b. darkness

3. Green plants give off the gas called
   a. nitrogen
   b. oxygen

4. Priestley's mouse was livelier when the jar contained
   a. a green plant
   b. nothing but air

B. Write a paragraph or two on this topic: "A Green Plant in Sunlight and in the Dark."

USING WHAT YOU KNOW 1. Why are animals dependent on green plants? How was this true of Priestley's mouse?

2. Would more oxygen be collected from a green plant on a bright day or on a cloudy day? Why?

ON YOUR OWN Your classroom may have an aquarium. On a sunny day observe some of the water plants. Perhaps you will see bubbles rise from them to the top of the water.

Count the bubbles. How could you find out whether plants give off more gas in sunlight or in shade?

2. The Importance of Light

Green plants produce oxygen but only when there is light. Moreover, a plant must be *green* to produce oxygen. It must have in its leaves a green substance called **chlorophyll** (klôr′ə-fil). A plant that is not green, such as a mushroom, has no chlorophyll in its cells. It cannot make oxygen, even in the brightest sunlight.

Somehow a plant with chlorophyll in its leaves produces oxygen, in light. It does something else, as well. It makes starch—a food.

The Food Maker

Starch is a food substance, as you know. It is a food substance that living things use. The green leaves of the geranium have this surprising property: they make a food substance, starch, when light reaches them. In fact this is true for *all* green plants, not just for geraniums.

Starch, you may remember, belongs to the class of substances known as carbohydrates. Scientists have done many experiments with green plants. The experiments show that *green plants make carbohydrates when light reaches them.* This process of making food substances by using light energy is called **photosynthesis** (fō′tō·sin′thə-sis).

During photosynthesis the green plant first makes glucose, a special kind of sugar. Then from this sugar, glucose, the plant makes starch. So a green plant has in it sugars and starches made by photosynthesis, sugars and starches made by using light energy, that is.

Now, all living things depend on these starches and sugars for food. This means that all living things de-

■

pend on the green plants that make these starches and sugars. **Living things depend on the process of photosynthesis going on in green plants.** ■

Remember, too, that the oxygen that living things need is made only by green plants, in light. You can see why green plants and photosynthesis are important, and why we want to know more about them.

Let's sum up these important facts:

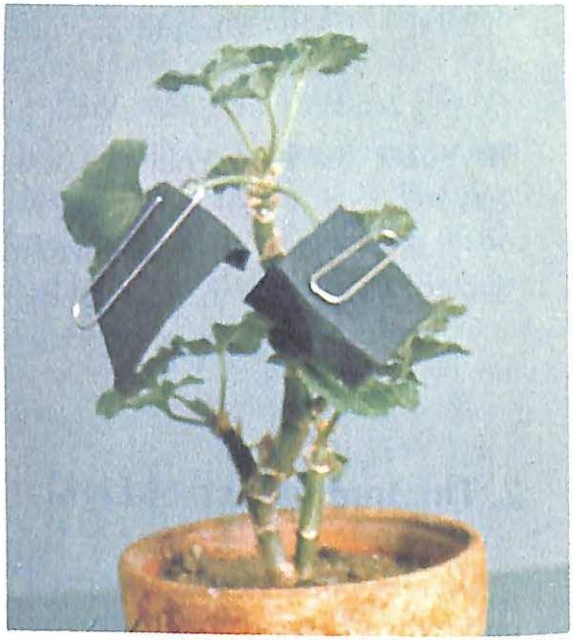
1. Green plants produce carbohydrates.

2. Green plants produce oxygen.

3. Green plants produce carbohydrates and oxygen only in light.

Scientists have tried to make carbohydrates as plants make them, by photosynthesis. So far they have failed. See for yourself how a green plant makes starch. Try the investigation on the opposite page.

AN INVESTIGATION



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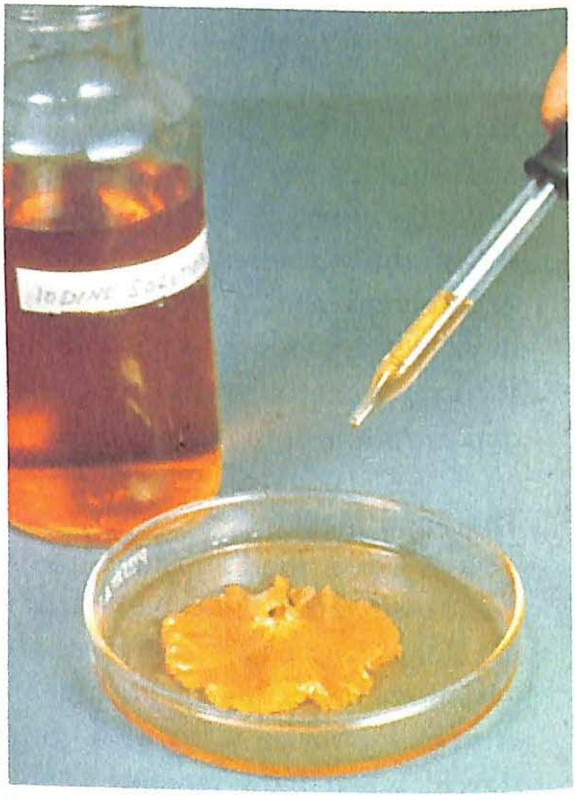

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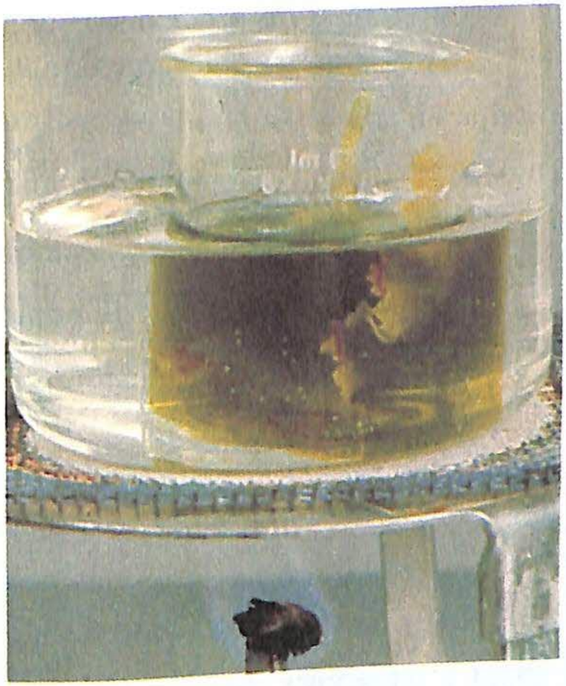
into What Happens to a Geranium Leaf in Light

Needed: a geranium plant, rubbing alcohol, black paper, string, paper clips, a pan, solution of iodine, a medicine dropper, three baby food jars

Fold a piece of black paper closely around a geranium leaf so that no light reaches the leaf. ■ Fasten with paper clips. Place a strip of black paper on another leaf so that half of the leaf is protected from light. Set the plant where it will get sunlight.

Three days later, prepare to test the geranium leaves. First the green substance in the leaves, the chlorophyll, must be taken out. Pour about an inch of rubbing alcohol into each jar. Label one jar **leaf in dark,** another jar **half leaf in dark,** and the third jar **leaf in light.** Cut off each of these leaves at the stem. Remove the paper. Put each leaf in the alcohol in its jar.



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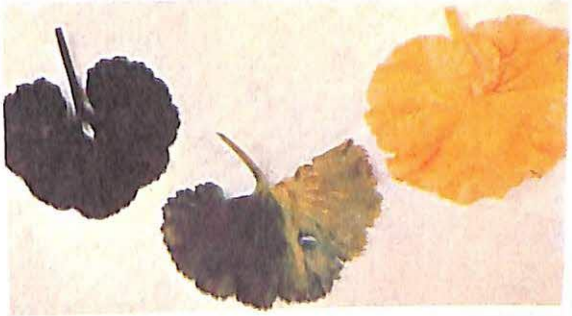

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The chlorophyll will be removed faster in warm alcohol. Heat some water in the pan. **Take the pan of hot water away from the heat.** Then place the jars in the hot water.

Shake each jar now and then. In time, the leaves will turn pale green or white. ● Wash the alcohol down the drain.

Now, with the medicine dropper, put iodine solution (1 drop in a half cup of water) on each leaf, just enough to cover the leaf. ▲ Iodine is a test for starch. When a blue-black color appears, it means that starch is present.

Here is what happened to the three geranium leaves in one investigation. ◆ Reason from this evidence. Does the iodine test show that starch is present? Is the starch found in the part of the geranium leaf open to light or closed to light?

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. In light, a green plant can make
   a. minerals b. carbohydrates
2. A green plant makes food substances by the process of
   a. chlorophyll b. photosynthesis
3. In light, green plants produce
   a. oxygen b. nitrogen
4. To carry on photosynthesis, a plant must have
   a. roots b. chlorophyll

B. Write a paragraph or two on this topic: "The Importance of Light to Green Plants."

USING WHAT YOU KNOW

Euglena (yōō·glē′nə) is a living thing made up of one cell. In this one cell it carries on all the activities of a living thing. The ameba is another one-celled living thing. Both euglena and ameba can move about in the water, like other one-celled living things. But euglena is different from other one-celled living things such as the ameba. Euglena has chlorophyll in it.

1. What can euglena do that an ameba can't do?
2. Do you think that euglena is an animal, a plant, or both?

ON YOUR OWN

Green leaves carry on photosynthesis. How many different shapes of leaves can you find near your home?

3. The Lonely Green Plant

There must be scientists who would like to have a blade of grass talk to them. For a green blade does something that chemists have not been able to do, in spite of all their efforts. The green blade makes starch in light. That is, it makes carbohydrates by photosynthesis.

The chemists have not given up, however. They believe that they are getting closer to solving the puzzle. They keep on asking questions and looking for answers.

What do green plants make carbohydrates from? Plants can't make something from nothing, after all. To make carbohydrates a green plant must have certain building blocks, certain elements. What are these elements, and where does a plant get them? Let's see if we can reason out an answer. What elements do green plants use to make carbohydrates?

Reasoning from the Evidence

We know some things about green plants that we can reason with.

Green plants need light energy.

Green plants give off oxygen.

Green plants make carbohydrates.

In other words, green plants in light produce carbohydrates and oxygen.

Now, we know that a carbohydrate is made up of atoms of carbon, atoms of hydrogen, and atoms of oxygen. We know that the oxygen produced by a green plant is made up of atoms of oxygen only. So to make carbohydrates and oxygen, the green plant must have a supply of *carbon*, *hydrogen*, and *oxygen* atoms. These are the building blocks.

Where can the plant get a supply of carbon, hydrogen, and oxygen atoms? Let's reason further.

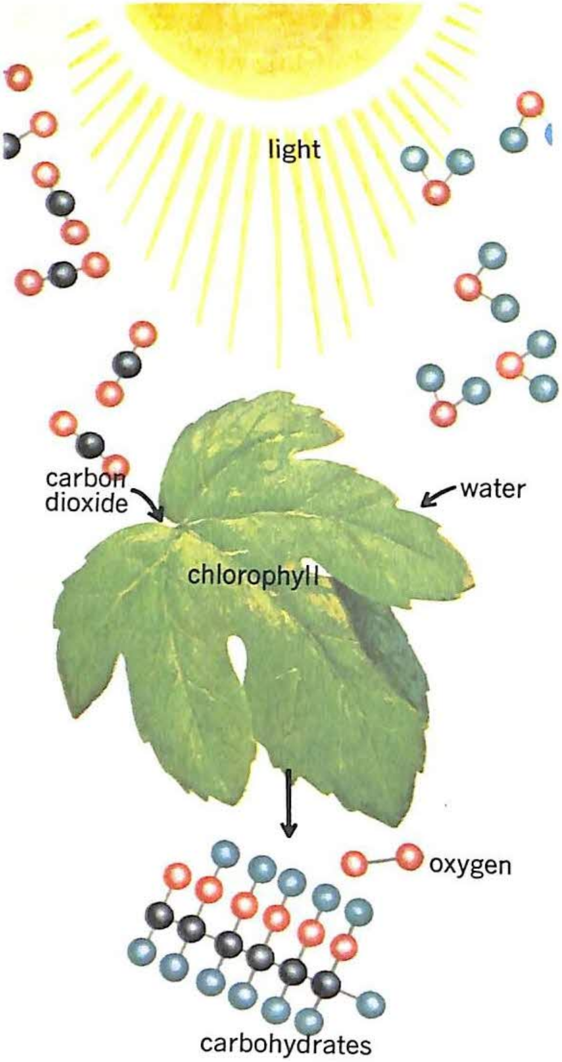
Plants take in water. Water is a compound of hydrogen and oxygen. There is a supply of *hydrogen* in water.

In the air around a plant there is carbon dioxide, which the plant takes in. There is a supply of *carbon* in the gas carbon dioxide.

Then there is a supply of *oxygen* in both the carbon dioxide gas and the water.

Now we can make a guess at the chemical reaction that might produce carbohydrates in a plant. Scientific work often starts with a guess, but not a wild guess. The guess of the scientist is based on what is known. It's sometimes called an educated guess. Or it can be called a hypothesis, of course. Our hypothesis is that, in a green plant and in light,

$$\textbf{carbon dioxide} + \textbf{water} \longrightarrow \textbf{carbohydrates} + \textbf{oxygen}$$



In fact, many experiments have shown that this *is* what happens. The hypothesis is correct. **Green plants make carbohydrates from carbon dioxide and water.**

Green plants make carbohydrates by the process of photosynthesis. To carry on photosynthesis, a plant must have light and chlorophyll. It must have carbon dioxide and water, as well. ■

Let's remind ourselves why this is important. It is important because the green plant is the food maker for the world. The green plant is the storer of energy. The energy is stored in the food the plant makes. When we eat green plants, we use *their* stored energy for *our* growth and work.

As you go on, you will see that plants make their own proteins and fats as well as carbohydrates. Green plants store great amounts of these substances. For instance, the potato stores starch, a carbohydrate. The peanut stores peanut oil, a fat. The soybean stores a great deal of protein, besides fats and carbohydrates.

We cannot live without green plants. Can green plants live without us? Can green plants live without animals? Collect some unusual evidence for yourself. Try the investigation on the opposite page.

The Independent Green Plant

We cannot live without green plants. Green plants can live without us, however. Green plants do not depend on us, but we depend on them.

Animals depend on green plants. Do green plants depend on animals? The green plant sealed in a bottle, in the investigation, is independent of any animals as far as we can see.

What about animals that we cannot see?

AN INVESTIGATION into a Sealed-in Plant

Needed: a large jar with a screw cap, some sand, green water plants, pond or aquarium water, plastic-coated adhesive tape

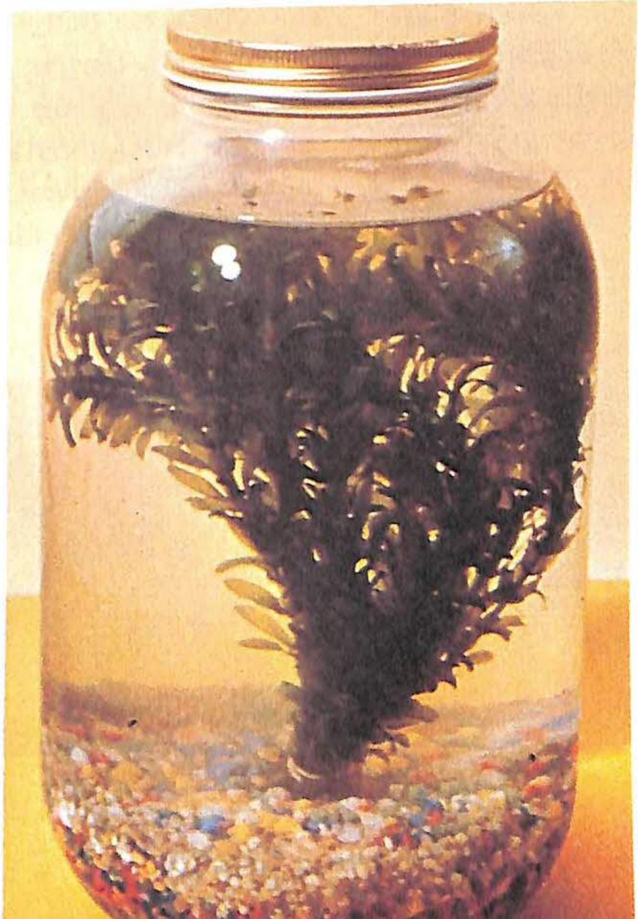
First, make an aquarium in the large jar. Put about 2 inches of clean sand in the bottom of the jar. Slowly add pond water or aquarium water until the jar is about half full. Then plant the green water plants in the sand, and fill the jar to the level shown.

Screw the cap on tightly. Wind plastic-coated adhesive tape around the cap and jar so that air cannot get in or out. Now the plants are sealed in the jar.

Place the jar where it will get some sunlight, but not very much. Don't let the jar get very hot or very cold. Observe the plants from day to day. Are they growing, or dying? For how long can they stay sealed in?

The water plant shown was in the jar for a few weeks. What happened in this trial?

Additional Investigation: Predict what will happen if some plants are sealed in a jar but are not exposed to light. Predict how long it will take to discover if your prediction is correct. Test your predictions.



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Some students investigated the water in which their sealed-in plants were growing. They took water and sand from different parts of the jar, made slides, and examined them under a microscope. They found protozoans, single-celled animals, like these. ■ Green plants and protozoans make good neighbors. Green plants give off oxygen; protozoans use oxygen. Protozoans give off carbon dioxide. Green plants use carbon dioxide.

The students found tiny water molds as well. Water molds are plants without any chlorophyll in them. Molds use the oxygen that green plants give off, and give off carbon dioxide which green plants can use.

What these students found, then, was that the green plants sealed in a jar were not living alone. The sealed-in green plants were living with other plants and animals too small to be seen with the unaided eye.

Can a green plant actually live all by itself in a sealed jar? Yes, but the investigation is very difficult to set up. For example, the seed from which the plant will grow must be treated so that molds and bacteria on the seed are killed. The soil and water in which the seed will be planted must have no living things in it. The sealed-in seed will grow and become a plant, because the substances that it needs for growth are there in the jar.

The green plant can live without animals. But animals cannot live without the green plant. All animals depend on green plants for energy. You will see how in the next section.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A carbohydrate is made up of carbon, hydrogen, and
   a. nitrogen b. oxygen
2. The green water plant gets its hydrogen from
   a. carbon dioxide b. water
3. The green water plant takes its carbon from
   a. a gas b. a liquid
4. A green plant can live without
   a. animals b. oxygen
5. A fish cannot live without
   a. green plants b. land

B. Write a paragraph or two on this topic: "How a Sealed-in Plant Lives."

USING WHAT YOU KNOW

A boy buys a glass tank for fish. He puts in some sand and fills the aquarium with water. What else would you suggest he put into the aquarium before he puts his fish in? Why?

ON YOUR OWN

Set up an aquarium as in the picture on page 240. If your water is taken from a city supply, let it stand in the aquarium for two days or so before you add the plants. Why? The city supply may use chlorine to purify the water. This chlorine may kill the green plants. Water exposed to air loses its chlorine.

4. We Seal in a Fish— And a Cow

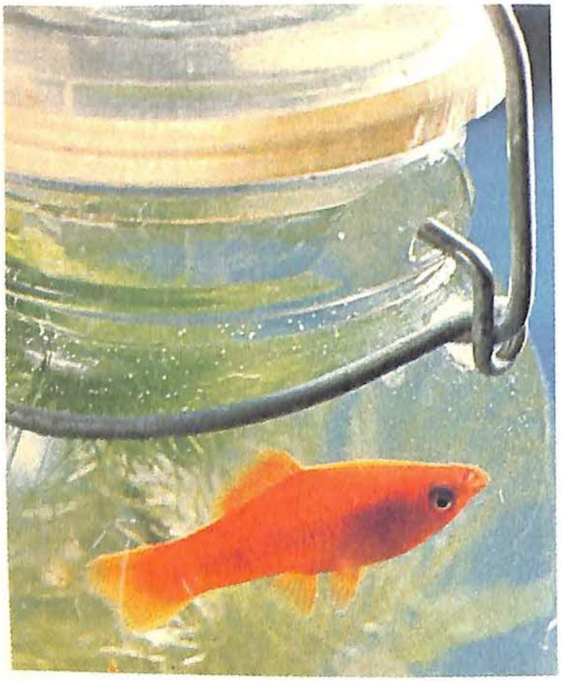
Green plants sealed into a jar can live for a long time. They can live, we know, because they get everything they need from their environment of water and soil and light.

Suppose now that we take such a jar of sealed-in plants, open it for a moment, and add a small fish. Then we seal the jar again. ■

What will happen now?

Will the fish live? Will the plants continue to live? We watch the sealed-in living things closely. Day by day they continue to thrive. Weeks go by, and it becomes plain that both fish and plants live with ease in the sealed-in world, inside the jar.

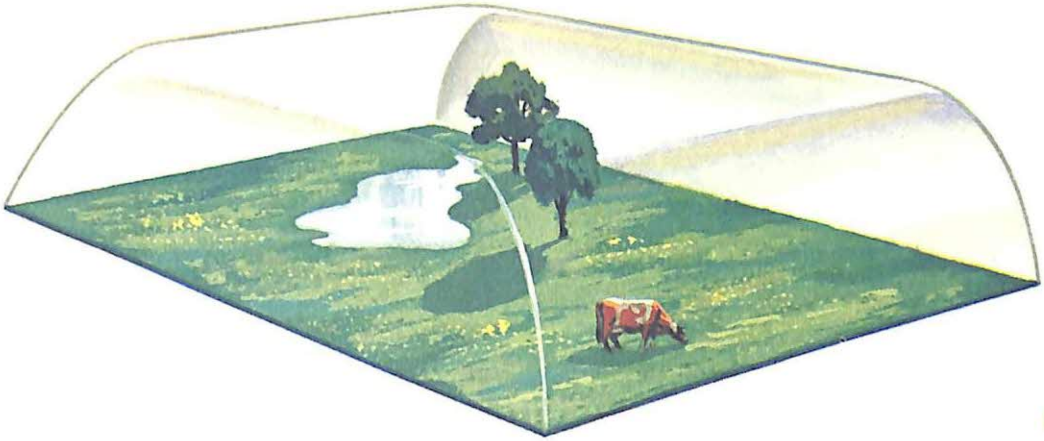
■



How does it happen that the fish can live in this little sealed-in world? Let us see what the fish must have to live. The fish must have oxygen. The green plants give off oxygen, which goes into the water. The fish takes that oxygen from the water.

The fish must have food. It must have carbohydrates, for example. We know that green plants make carbohydrates. The fish can get carbohydrates from the plants it eats. However, the fish needs fats and proteins as well as carbohydrates. The green plants make fats. They do even more. The water contains minerals which the plants take in and combine with carbohydrates. In this way, the plant makes proteins, too.

Thus, the small fish can get from the green plants all the food substances it needs, and it can grow. It can live sealed in the jar because it has around it all the things a fish requires to stay alive. The same thing is true of the sealed-in green plants. Their surroundings contain the things they need to stay alive. The needs of both fish and plants are being met by their environment, that is, by their surroundings. The environment of the sealed-in fish seems to us very small and limited, and we are surprised that the fish thrives in it. But size is not what counts, we can see now. What counts is that the environment supplies what the living thing needs.



Seal in a Cow?

What if a different kind of animal were sealed in?

It would be hard to seal in a cow, certainly, but imagine a cow on a piece of land about the size of a football field. There is grass and water. A plastic dome seals in the cow and the field. ●

Will the cow live?

What does a cow eat and drink? Mostly grass and water, of course. What does it breathe? Air. So the things that the cow needs to stay alive are sealed in with it, under the dome. In other words, the cow has the environment that it needs to live.

Green plants, a fish, a cow, all depend on their environment for life. They cannot live by themselves. If the environment does not supply what they need, they cannot live. If the green plants in the water do not produce oxygen, the fish cannot live. If the grass does not grow, the cow cannot live.

In a way, then, fish and cow are sealed into their own environments. Neither fish nor cow can leave its environment and live. In fact, no plant or animal can leave its environment and live. Every living thing is, in a way, sealed into an environment just as if it were sealed into a jar, even though it appears to be free.

All plants and animals—and you—are sealed in on this planet, Earth. For here on Earth we have the environment we need to live. Without this environment, plants and animals and you cannot live. Indeed, when we venture into a different environment out in space or below the sea, we make sure to take with us the things we need. We make sure that we take our environment with us, or as much of it as we need. The skin diver takes tanks of air along with him. The traveler crossing a desert takes food and water.

We are sealed in on the Earth. We and our environment are one.

ON YOUR OWN

1. Name two animals that eat plants only.
2. Name two animals that feed on animals that eat plants only.

5. The Green Plants That Saved the Limeys

British sailors were once nicknamed "limeys." They got this nickname because even sailors on the sea depend on green plants. ■

Until about two hundred years ago, sailors found long voyages very hard. Their food was poor. It was mostly dried meat and a very tough kind of biscuit. There were no fruits or fresh vegetables because there was no way to keep them from rotting in those days. To make matters worse, on a long voyage many sailors became ill with a strange disease called *scurvy* (skûr′vē). A sailor with scurvy became weak and was unable to work. Tiny blood vessels under his skin broke, and his gums bled. He might die if the disease were not halted.

Men were searching for a cure for scurvy, of course. Among them was a doctor for the British Navy, named James Lind.

Dr. Lind had an idea. The more he read, the more he thought that somehow, eating fruits, such as oranges and lemons, had something to do with curing scurvy. So he designed an investigation and carried it out.

He divided the sailors on one ship who had scurvy into groups. One group received their regular food and lemons and oranges. Other groups received their regular food and various treatments then given for scurvy.

Dr. Lind's investigation produced clear evidence. The sailors who received the regular food and fresh fruit were cured of scurvy. The sailors who had regular food and the other treatments were not cured of scurvy.

Thus it was found that something in fresh fruits such as lemons, oranges, and limes could prevent scurvy, or cure it. British ships began to carry lemons or limes on long voyages, and their sailors no longer got scurvy. That is how British sailors came to be called "limeys."

Are You a Limey?

You don't get scurvy. You don't have to eat limes. But you are a limey, in a way.

Do you drink orange juice, or grapefruit juice, or lemonade? If you do, you drink the juice of fruits that are in the same family as limes. Scientists have studied these fruits and their juices, and have found in them substances called **vitamins.** There are a number of different vitamins, but oranges, grapefruit, lemons, and limes contain a good deal of one particular vitamin. It is called vitamin C. Vitamin C helps prevent scurvy. If you drink orange or grapefruit juice, or lemonade, you are already getting your vitamin C, and preventing scurvy. You are already a limey, in a way.

Drinking tomato juice, or eating tomatoes or certain green vegetables, provides plenty of vitamin C. Green plants and many of their fruits have this important vitamin in them. They have other vitamins as well. Or they may have substances which can be changed into vitamins. Green vegetables and fruits have vitamin B, for instance. Carrots have a compound in them which animals can change to vitamin A. The liver of a fish like the cod has both vitamin A and vitamin D in it.

As we will see, all these vitamins are very important to health.

Starving on Three Meals a Day

You would starve to death if the vitamins were removed from your food, no matter how much you ate.

Without vitamin B, for example, a person soon loses his appetite. His muscles lose their strength, and his nerves do not keep his body organs working together. He becomes so weak that he cannot work. He has the disease called *beriberi* (ber′ē·ber′ē).

Without vitamin A, a person gets colds easily and his skin becomes dry and scaly. He is not able to see well in the dark, a condition known as night blindness. Without vitamin D, bones do not grow well. A person may get the disease called *rickets* (rik′its), in which the leg bones are bowed and the chest bones poorly formed. And, as you may know, a person without vitamin C can get scurvy.

We cannot keep in good health without vitamins. In fact, all living things must have vitamins. Where are vitamins made? In the green plant cells, of course. Living things depend on the green cells to make vitamins.

This is one more example of our dependence on green plants.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Dr. Lind's experiment gave clear evidence that fruits such as oranges and lemons had something in them that prevented or cured scurvy. The sailors who ate these fruits
   a. were cured of scurvy b. were not cured of scurvy

2. Scurvy is prevented by
   a. vitamin C b. vitamin D

3. You can get plenty of vitamin C in
   a. green vegetables b. meat

4. Rickets is a disease caused by lack of
   a. vitamin B b. vitamin D

B. Write a paragraph or two on this topic: "The Vitamins That Plants Make."

USING WHAT YOU KNOW

1. A boy eats only a frankfurter and roll for his lunch. Name a vitamin that is probably missing from this meal.

2. Not being able to see well in the dark is called night blindness. Why are carrots good for it?

6. Are You Sealed In?

Milk is a remarkable food.

First, milk contains vitamins you need every day. Vitamins A, B, C, and D are present in milk (but not very much vitamin C).

Then there are proteins, carbohydrates, and fats in milk. You need these different food substances for growth and energy. There are minerals in milk as well, especially calcium and phosphorus. Your cells build the calcium and phosphorus into your bones. The vitamin D in milk helps your body make use of these minerals.

With all these things in it, milk is a remarkable food.

From Environment into Body

How do all these substances get into milk?

The roots of green plants take in minerals from the soil. The cow that makes the milk eats green plants. Some of the minerals in the plants go to the cow's body cells and are used there. Some of the minerals go into the cow's milk.

Green plants contain proteins, carbohydrates, and fats. Some of these build the cow's body, some go into the cow's milk.

The vitamins in the cow's milk also start with green plants.

All these minerals, food substances, and vitamins in milk, we need. However, we need other things as well, things not found in milk. For example, we need iron.

What do we need iron for? As you know, iron is an important part of the compound in the blood called hemoglobin. Hemoglobin has an important job. It carries oxygen to the cells of the body. Without hemoglobin, oxidation could not take place, and cells would die. Without iron, hemoglobin could not do its work.

How does the body get iron, then? There is a great deal of iron in soil. Green plants take this mineral, iron, into their cells and build certain compounds. When an animal eats the green plants, some of the iron from the plants goes into the animal's body cells. Red meat and liver are animal body cells rich in iron. We eat the animal's meat and use the iron to help build hemoglobin.

Vitamins, minerals, carbohydrates, fats, proteins—we need all of these substances and water as well. If we don't get enough of any of them we don't get what we need to grow strong and healthy. We do get enough of all these food substances if we have milk, orange juice, meats, fish or eggs, and green vegetables every day.

Vitamins, minerals, carbohydrates, fats, proteins—we need them all, and *all of them come to us by way of the green plant cell.* Can you find one kind of food that cannot be traced to a green plant? The shark does not eat plants. It eats other animals. But what do those other animals eat? A tiger doesn't eat plants—but the animals it feeds on do. Any food can be traced back to a green plant. All food comes by way of cells with chlorophyll in them. Green plants are truly the food builders of the world.

You, like all other living things, depend on green plants. You depend on chlorophyll. Of course chlorophyll depends on sunlight to do its work. Without the Sun's light, green plants cannot build food compounds. So you depend on the Sun, really, for every bite of food that you eat. All living things depend on the Sun. Without sunlight there would be no life.

7. Cells That Built Our Fuel Supplies

Millions upon millions of years ago, the ancient seas swarmed with tiny animals. These animals were so tiny that a small bucket could hold more of them than there are people in the United States. They were single-celled animals, protozoans.

Each protozoan lived in a tiny shell of calcium carbonate, which it made. Each fed on plants in the sea. Each stored any extra food that its body could not use, much as we do. When we eat more food than our bodies can use for growth and energy, our bodies store the extra food as fat. The ancient single-celled protozoans also stored the fat in liquid form, as oil.

Cells That Built the Oil Fields

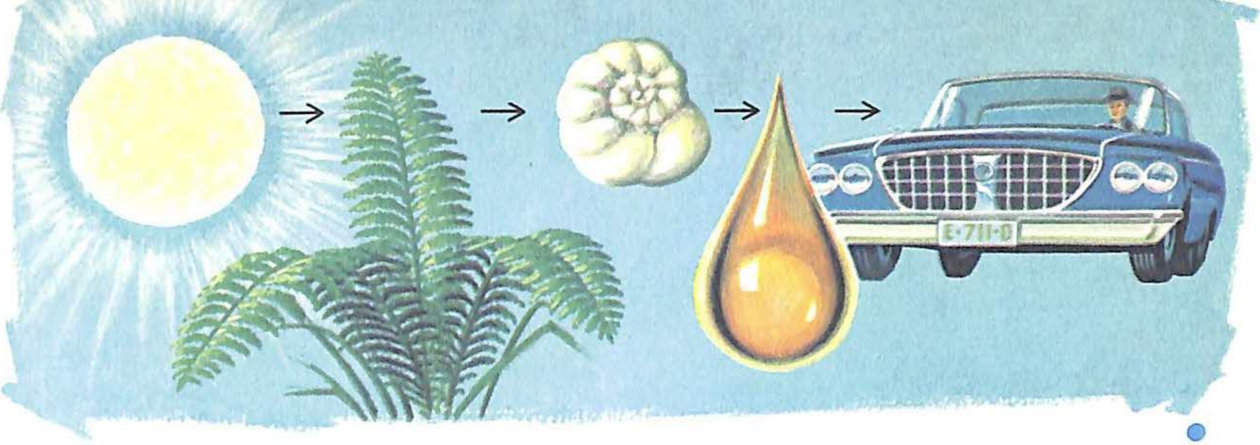
If you rub a peanut on paper, an oily mark appears on the paper. The cells of a peanut store extra food as oil. So did the ancient protozoans. An animal that eats the peanut may store some of the oil.

As the protozoans died, they dropped to the bottom of the sea. There millions upon millions of the tiny shells built up layers of sediment. In time, these layers hardened into sedimentary rock, into chalk. Something else probably happened as well. The stored oil that these protozoans carried gathered under the rock. It collected in vast amounts under domes of rock. We drill through these domes of rock for the oil. We burn this oil in our furnaces. We use this oil to make gasoline. And this is the oil that the tiny protozoans made.

Stored Energy

Why is this oil so important to us? It contains *energy*. It is the energy of oil that runs our furnaces, cars, trucks, ships, locomotives, and many other machines.

Where does this important energy come from? From the stored oil of those ancient protozoans. Now, go back a step. Where did the protozoans get their energy? From the green plants they ate. Go back one more step. Where did the green plants get their energy? From the Sun, of course. So it is right to say that the energy of oil comes from the Sun. Oil stores the energy of the Sun.



The Sun gives off light energy. Green plants capture that energy during photosynthesis. They turn the light energy of the Sun into chemical energy. The green plants are eaten by protozoans. The Sun's energy is passed on to the protozoans. They store it as chemical energy in oil.

We gather the oil, and make use of its chemical energy. Thus it is really the energy of the Sun that heats our homes, runs our automobiles, and ● does many other things. ●

Cells That Built Coal Fields

Millions upon millions of years ago, the Earth was not as it is now. It was very warm and humid then. There were great swamps crowded with plants, including forests of giant ferns. ▲ All through these swamps roamed giant animals, some larger ▲

than elephants. Through the forests flew huge insects, such as giant dragonflies.

In time, the tree ferns and other plants died and fell into the water. Other trees grew, died, and fell on the trees already fallen. Under this growing weight, fallen trees sank deep in the swamps. Layer upon layer of dead trees and plants pressed on the layers below.

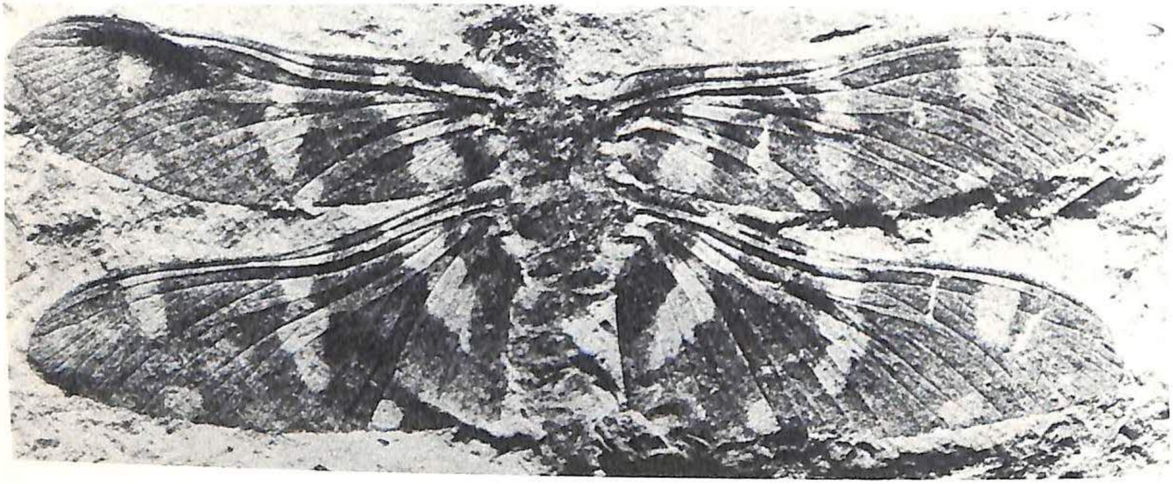
Sometimes the water covering a swamp became deeper and deeper. In time, the swamp lay under a lake. Streams brought sediment into the lake, and the sediment began to cover the layers of trees and plants.

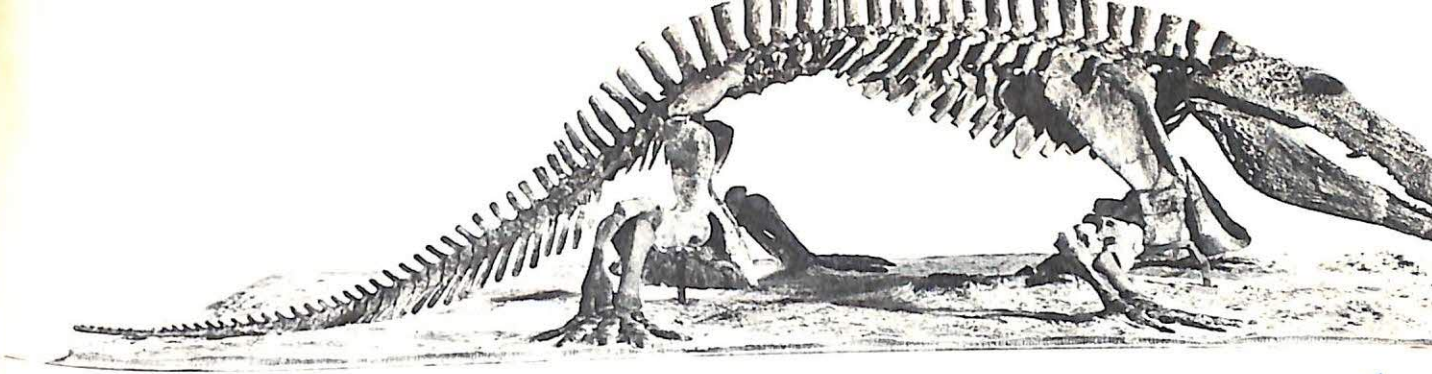
The Weight of Sediment

For thousands of years sediment collected on the bottom of the lake. Layer upon layer of sediment covered the trees and plants, weighing down on them more and more. As the sediment pressed down on the trees, the pressure produced *heat*. The dead trees and plants were heated in a kind of natural oven, underground.

Oxygen could not reach the plants and trees below the sediment. So they did not burn. But under the pressure and heat, the trees and plants slowly turned into coal.

How do we know that such ancient forests once existed, long before man appeared on Earth? How do we know that huge animals roamed such forests and huge insects flew among their





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strange leaves? We know by the fossils. In layers of coal and sedimentary rock laid down millions of years ago, we find fossil leaves like these. ■ No plant now alive has such leaves. And this fossil of a giant dragonfly has a wingspread of more than a foot. ● (A dragonfly today may have a wingspread of 3 or 4 inches.) The fossil bones of this huge amphibian are now in the American Museum of Natural History in New York City. ▲ These plants and animals were found in sedimentary rock that also held coal. They must have been alive when that coal was being formed.

Captured Energy in Coal

A lump of coal contains energy. That is why we find coal so useful, of course. Let us look for a moment at how far that energy has come before we use it.

Green plants have cells with chlorophyll in them. In sunlight these green cells build carbohydrates. Photosynthesis goes on, in other words, and the plants make food substances.

With these food substances a tree can build more wood. The tree dies. Over thousands of years the wood is changed, by pressure and heat, into coal. Thus the energy of the Sun that was captured by green plants is sealed into coal.

We have learned how to use coal. When we do so, we are using the stored energy of the Sun. Thus when we burn oil or coal, we release the Sun's energy.

BEFORE YOU GO ON

A. Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Oil was stored by
   a. single-celled animals b. trees

2. Coal came from
   a. plants   b. animals

3. Both oil and coal can be traced back to
   a. rocks   b. living things

4. The energy of both oil and coal can be traced back to
   a. the Sun   b. the soil

B. Write a paragraph or two on this topic: "Cells That Built Our Fuel Supplies."

USING WHAT YOU KNOW

1. A boy collected some coal. In one piece of coal, he found the print of a leaf. It was the leaf of a plant which lived millions of years ago. How did a leaf print get in coal?

2. The rock in which oil is found is made up of the compound calcium carbonate.

a. What were the shells of the protozoans which stored the oil made of?

b. Suppose you could look at one of these limestone rocks (rocks made of calcium carbonate) under the microscope. What kind of shells might you find?

3. Oil and coal are made up mainly of substances called hydrocarbons (hī′drə·kär′bənz). Hydrocarbons are made up of the elements hydrogen and carbon. Where did these elements come from?

ON YOUR OWN

1. In what part of these lands is most oil found?
   a. North America   c. Europe
   b. South America   d. Asia

Different groups in your classroom might report on each of these areas.

2. In what part of these lands is coal found?
   a. North America   c. Europe
   b. South America   d. Asia

8. Cells That Make Clothing

Green plant cells supply us with food. Green plant cells build trees which supply wood to build with. Green plant cells harness the energy of the Sun, in coal and oil and natural gas. Both plant and animals cells are used to clothe us, too!

Are you wearing something made of cotton, or wool, or silk? All these materials are made of cells or made by cells. Cotton comes from the cotton plant. It is made by plant cells. Wool comes from sheep. It is really animal hair, made by animal cells. Silk is made by another animal, a silkworm. Here are some silkworms, making their cocoons of silk. ■

Cells as Builders

Wool is made up of animal cells and contains protein. Cotton is made of plant cells and is mainly cellulose. Cellulose is found in the cell walls of plant cells. A cotton shirt or blouse is made up of cellulose. Both wool and cotton, however, are composed of cells.

Cells are the builders of many things on this planet Earth. As cells divide, living things grow. So cells are builders of living things. They are the builders of the parts of a living thing that are not alive, too. Bones, teeth, and hair, for instance, are made by cells.

Cells build food. As photosynthesis takes place in green plant cells, the plants make proteins, carbohydrates, and fats. These are our foods. Then, too, green cells helped make the oil, coal, and gas we use, and the clothing we wear.

The green plant cell is surely one of the most important cells in the world.

Can you tell the difference between cotton and wool? See for yourself—try the investigations on the following pages.

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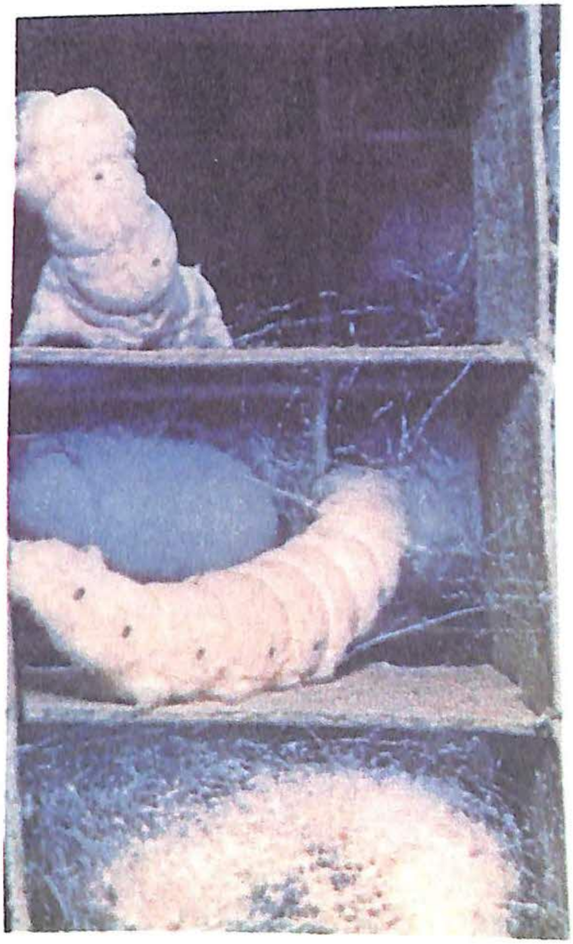

AN INVESTIGATION into Identifying Wool and Cotton

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Needed: a bowl, some cotton, some metal foil, and some wool

Cut a piece of cotton cloth about an inch long and wide. Or take a piece of absorbent cotton about the size of a lima bean. Place the cotton in the bowl, light it, and let it burn. ■ The substance left is carbon. ● Notice that there is no odor of burning hair. No protein has been burned.

Place a piece of woolen cloth about an inch long and wide in the bowl and light it. ▲ Let it burn. Carbon is left. ◆ But notice the odor of burning hair. Wool is made of *animal* cells, which have much protein in them.

Protein has nitrogen in it, and the nitrogen forms different compounds when protein is burned. One compound formed is ammonia, which helps give burning protein its special odor. This odor is one way of telling wool from cotton.

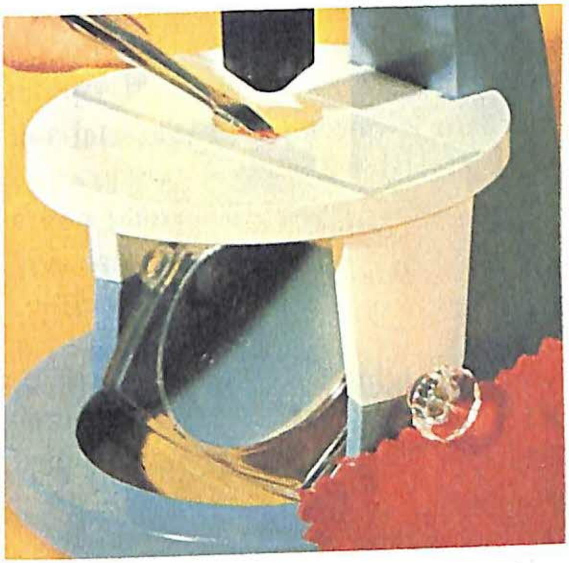
◆

AN INVESTIGATION into Cotton and Wool Under the Microscope

Needed: a piece of wool, a piece of cotton, a microscope, a microscope slide, and a wooden toothpick

Use the toothpick to pull out a few threads from the piece of wool. Place the threads on the slide and view them under the microscope. ■ The small sections are dead, flat cells. ● Wool is animal hair and is made up of cells. Your hair has cells much like these.

Pull out a few fibers of cotton from the piece of cotton cloth and examine them under the microscope. ▲ Are there cells to be seen in a fiber of cotton? ◆ How would you find out? Compare what you see with the wool fibres you have examined.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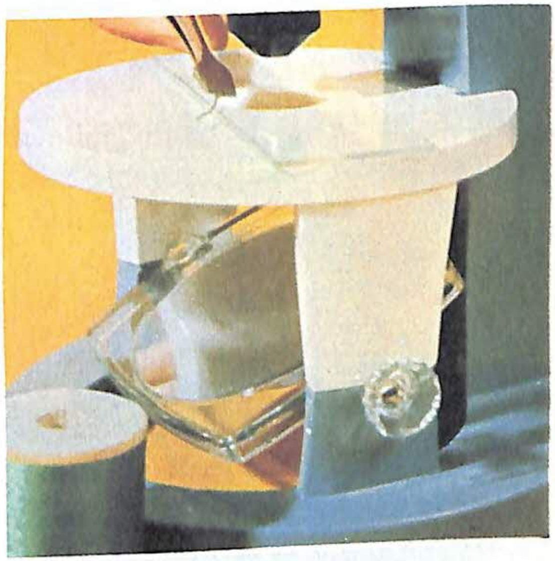
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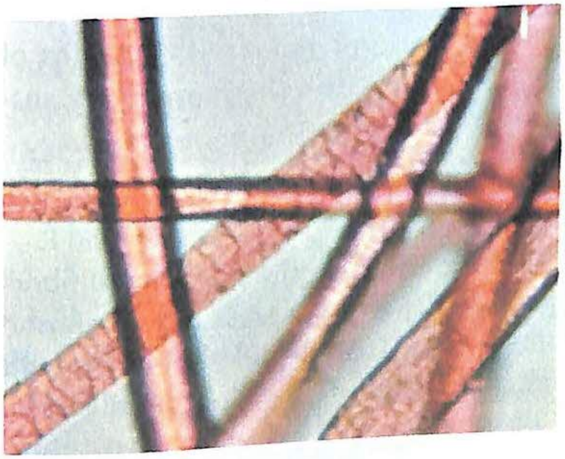
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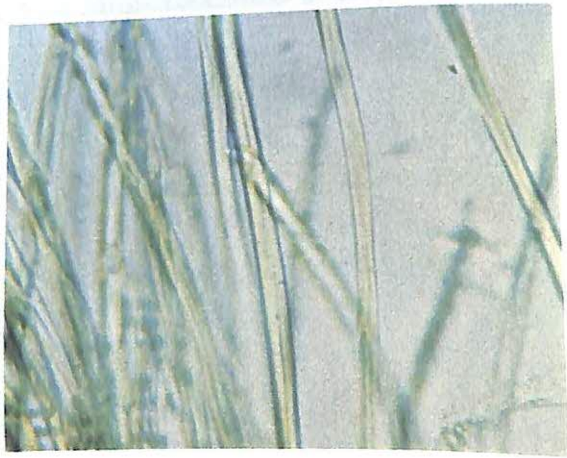
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BEFORE YOU GO ON

Study the statements below and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The cells that build wool come from
   a. a plant b. an animal
2. Wool differs from cotton in that it contains a
   a. protein b. carbohydrate
3. Under the microscope the remains of cells can be seen in
   a. wool b. cotton
4. The substance found in cotton but not in wool is
   a. cellulose b. carbon

USING WHAT YOU KNOW

1. In the following list there is one kind of material not built by living cells. Which material is it?

paper
wood
glass
cotton
wool

2. A robbery took place one night. One clue was a bit of cloth that was caught on a nail.

Two men were suspected of the robbery. Both had tears in their clothing. One had a tear in a wool coat. Another had a tear in a cotton raincoat.

The detectives looked at the piece of cloth from the nail under the microscope. It was made of hairs with remains of cells in them. Which of the two men was the more likely suspect? Why?

ON YOUR OWN

There are materials not made by cells, the man-made fibers —nylon, Dacron, and plastics of many kinds. Build an exhibit of materials used in homes. Collect materials made by cells and materials that do not have their beginning in cells. You might arrange them for a bulletin-board exhibit.

9. The Main Concept: The Sun's Energy Captured

Scientists have tried for many years to do what green plants do every day all over the world. Scientists have tried to make carbohydrates from carbon dioxide and water. Scientists have failed—so far.

The Sun's light energy streams onto the Earth. Some of it heats the Earth. Some is captured by the chlorophyll in green plants. Thus one kind of energy is changed into another. Light energy from the Sun is changed into chemical energy in a plant. Thus the Sun's energy is captured and stored in green plant cells by chemical action. We call this chemical action photosynthesis.

In photosynthesis,

carbon dioxide + **water** ⟶
with light and
chlorophyll
carbohydrates + **oxygen**

It is chlorophyll that captures the Sun's energy and makes this chemical reaction possible. Some scientists say that this is the most important chemical reaction in the world.

The green plant cell uses light energy to build our food, and to build many of the substances we use for living, such as fuel and clothing. All of us are dependent on the green plant cell.

However, light energy and chlorophyll are not enough. A seed by itself will not grow. To grow, the seed must have the right environment. Geraniums, rabbits, raspberries, crabs, corn, cows, you—all must have their proper environments. It is the environment that gives a living thing substances for growth and activity.

Every living thing depends on its environment for life. This is a simple idea. Yet it is one of the most important ideas in science.

Living things depend on their environment. What is the environment? Is it only soil, water, air, and light? No, it is more. The environment has in it living things as well.

Animals depend on green plants in their environment. Remove the green plants and all living things would die, in time. The tiger feeds on the zebra. The zebra feeds on green plants. You feed on other animals and plants.

All living things depend on each other and on the environment.

Fixing the Main Concepts

TESTING YOURSELF

A. Test your understanding of important concepts in this unit by doing these problems.

1. A mushroom is a plant. The cells of mushrooms have no chlorophyll in them. This must mean that the mushroom cannot carry on

a. oxidation
b. photosynthesis
c. excretion
d. reproduction

2. A glass jar was filled with air. A growing green plant, in its pot of soil, was put into the jar. The amount of carbon dioxide in the air in the jar was known. After 24 hours, there was a little more carbon dioxide in the jar than had been there at the beginning. So the plant and jar must have been placed in

a. darkness
b. light
c. heat
d. cold

3. Sunlight is the basis of food-making in plants. In a way, then, food has captured light energy. Which of these food substances that you eat or drink does not come from captured light energy?

a. sugar
b. starch
c. milk
d. iron

4. When photosynthesis is carried on, a gas is given off. This gas is used in your body cells to oxidize food substances. The gas is

a. nitrogen
b. oxygen
c. carbon dioxide
d. water vapor

B. Test your understanding of the concepts in this unit with this problem.

A main concept of this unit can be written as a chemical reaction. Here it is:

carbon dioxide + water ⟶ sugar + oxygen

We call this reaction photosynthesis. However, photosynthesis cannot go on unless certain conditions are present. Which of the following conditions must be present? Why?

1. The plant should be under water.
2. The plant should have chlorophyll.
3. The plant should have light.
4. The plant should have nitrogen.
5. The plant should have carbon dioxide.
6. The plant should be in complete darkness.
7. The plant should be colorless.

ON YOUR OWN

Investigations and Projects

A Collection of New Materials

Plant and animal cells make up many different materials, such as wool, cotton, leather, ivory, and others. There are materials which are not made of cells. Cellophane, nylon, Dacron, and plastics are some of these materials. Make a collection of the new materials which are coming out of the laboratories. Make an exhibit of these materials for your school. A committee of your classmates might take part in making this collection.

Write the story of each new material for the exhibit. In the story answer questions such as these:

What is the material made of?
What are its uses?
Who was the inventor?
How did he come to invent it?

FOR YOUR READING

1. *This Green World,* by Rutherford Platt, published by Dodd, Mead, New York, 1942. This little book looks into the structure of plants, how they take in water, grow, carry on photosynthesis, and bloom.

2. *Miracle Fabrics,* by Ellsworth Newcomb and Hugh Kenny, published by Putnam, New York, 1958. The authors begin with the story of the earliest fabrics and weaving tools, and end with the story of man-made fibers, such as nylon and Dacron.

3. *Strange Plants and Their Ways*, by Ross E. Hutchins, published by Rand McNally, Chicago, 1958. In stories and in pictures, the authors describe photosynthesis and reproduction in such strange plants as mistletoe, walking trees, lichens, and slime molds.

GOING FURTHER

An Investigation

The green plant cell needs a special kind of environment in which to do its work. For instance, chlorophyll cannot do its work without light.

What kind of light is best, however? Sunlight is made up of ultraviolet, violet, blue, green, yellow, orange, red, and infrared light.

In what light does the green plant cell do its work best?

Here are some clues which may help you design an investigation into this question.

1. Green plant cells are doing their work best when they *grow* best.

2. One way to compare growing plants is to count the new leaves, the ones formed after the investigation has begun.

3. One way to grow plants in different kinds of light is under colored cellophane or plastic.

4. Be sure to grow some plants under clear cellophane or plastic, as well.

5. Water plants may be very convenient for this investigation. For instance, the water plant elodea can be grown in test tubes. Each test tube can be wrapped in colored cellophane.

Can you design an investigation now?

A New View of Living Things

You'd think it would be easy to find out that most living things are made up of cells.

The Greek scientist Aristotle, who lived about 2,300 years ago, knew a great deal about living things. He was one of the first to group, or classify, living things. However, he didn't know they were made up of cells. Why? Because the microscope hadn't been invented. The microscope wasn't invented until about the year 1590 by a Dutchman, Zacharias Janssen. It wasn't till 1675 that Anton van Leeuwenhoek (lā′vən·ho͞ok) began to study single-celled animals. ■ He built his own microscopes. He was first to describe the spiral vorticella.

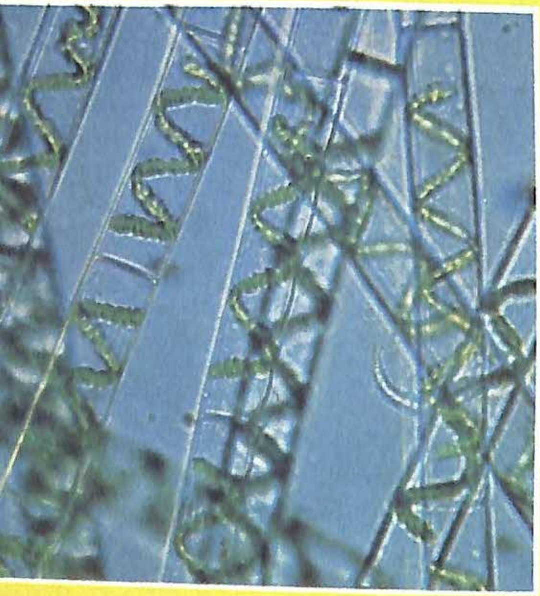
■

Between the years 1650–1665, Robert Hooke had looked through a microscope at a thin piece of cork. What he saw reminded him of the small rooms called cells in which monks live in a monastery. So he called the little spaces cells. Of course he didn't see living cells; he saw the woody cell walls of the cork.

After Hooke, many biologists began to use the microscope. Whether they studied geraniums or willows, roses or oaks, mice or sparrows, monkeys or goats, sheep or cows—whatever living things they studied, they saw cells. Especially interested in cells was one Matthias Schleiden, who spent his life studying the structure of plants. So too was Theodor Schwann, who spent his life studying the structure of animals. In 1839 they brought their studies together and stated:

All animals and plants are made up of cells.

Now, of course, you know this. *You* know more about the microscopic structure of plants and animals than did the greatest biologist in 1800. So you are no doubt surprised that this statement was so important. But think: it took man almost 50,000 years, since he began to grow animals and plants, to learn this. It took a long time to see this *hidden likeness* in all living things.



Today we take it for granted. When we see a living thing, we take it for granted that it is made up of cells. Yet it took almost 100 years, after Hooke thought of the word "cell," for this great concept to be really understood. All living things are made up of cells.

Structure and Function

Schleiden and Schwann went further. Like biologists before them, they observed that cells did certain things. Cells in the body did special jobs. In other words, cells have special *func-*

tions, as you know. For instance, you know that nerve cells have the function of carrying messages. Red blood cells have the function of carrying oxygen. Skin cells have the function of protecting the tissues under them.

Green plant cells have a very special function: they make sugar. Green cells are the cells that can capture the Sun's energy. They can use this energy to make sugar. Because sugar is the basic food substance from which other foods are made, all of us depend on the green plant cell. In other words, we depend on the *structure* of the plant cell. We depend on its chloroplasts, which contain the green substance chlorophyll. ■ We depend on its *function*. The green plant cell makes the food upon which the world depends. ●

So Schleiden and Schwann were able to say as well:

The cell is the unit of structure and function in living things.

The cells of the organism are not scattered about. They are organized into tissues, such as nerve tissue, and muscle tissue. The tissues are organized into organs, such as kidneys, heart, lungs, brain. The organs are organized into organ systems, such as the digestive system, nervous system, circulatory system. Finally the systems, all of them, are beautifully organized into the organism. You are

●

an organism, beautifully organized. The smallest part of this beautiful organization is the cell. The cell is the unit of structure and function in you, as it is in all living things.

Organisms are made up of cells.

The unit of structure and function in the organism is the cell.

■

The Cell as a Beginning

We know something more about living things and the cells that make them up. We know that elephants reproduce elephants and ducks reproduce ducks. We don't expect an alligator to hatch out of a hen's egg. And we know why.

It wasn't always known why. Only in the past 100 years have scientists come to know that within the egg cell lie the beginnings of a living thing like a duck. A many-celled living thing begins with one egg cell. (Single-celled living things also come from one cell.) In that one cell are the chromosomes. These chromosomes have in them a kind of code, a chemical message, which makes a cell produce a certain organism. The chemical message in a duck's chromosomes makes the egg produce a duck. ■ A paramecium cell has chromosomes with a code to produce another paramecium. So like begets like.

When the cell of a paramecium divides, the chromosomes divide. Each new paramecium has chromosomes like that of its parent. The chromosomes which made a duck are passed on to the duck's young. The chromosomes are passed on as the cells divide. Parents pass on their chromosomes to their young.

As you will learn later, chromosomes can change. When they change, the living thing changes.

Our study of living things brings another concept about life into the open:

Organisms are reproduced from cells.

When they reproduce, organisms produce other organisms like themselves.

So the study of cells has brought us some concepts which help us to understand all living things.

Here is a famous animal, a tortoise. ● Perhaps you have never seen a tortoise alive. Yet you know these things about it:

As a living thing, the tortoise is made up of cells. *Living things are made up of cells.*

The cells within the tortoise are its smallest units. *The cells of a living thing are the units of its structure and its function.*

The tortoise came from an egg cell. *Organisms begin their lives as cells.*

When the tortoise reproduces, it will reproduce other tortoises. *Organisms reproduce other organisms like themselves.*

●

CONCEPTUAL SCHEME
The universe is in constant change.

(*Text pages 270–303*)

Unit Seven
BUILDING BLOCKS OF THE STARS

UNIT CONCEPT
Bodies in space, as well as their matter and energy, are in constant change.

Children examine the evidence gathered by astronomers using special tools and develop the understanding that the Sun, Moon, and other bodies in space are in constant change. Light from the stars is the chief source of evidence.

A VIEW OF THE UNIT

A Preview of the Concepts

Children are introduced to the immensity of space as seen through a telescope. As the Earth turns, the telescope must turn to keep the stars in view. Children learn that the objects around them are visible only if light is reflected by, or bounced off, the objects. For this reason, mirrors in telescopes can collect light for better viewing. Direct light can be scattered by prisms, and the spectrum can be seen as it is reflected to the eye from an object such as a mirror or a screen. The color spectrum of visible light does not reveal the invisible infrared and ultraviolet bands. There are other bands beyond the infrared and ultraviolet which are used for such purposes as X rays and radio and television communication; but the waves in these bands, while traveling at the speed of light, are largely beyond the scope of this unit.

Theories of the Nature of Light

The study of light has produced two theories. The wave theory is the basis for assigning different frequencies to different colors. The term *frequency* perhaps needs explanation; it is the number of wavelengths that pass a point in space in a given time. The speed of light is a constant, 186,000 miles per second. The equation for the relationship between wavelength and frequency is $\textit{speed of light} = \textit{wavelength} \times \textit{frequency}$. It is easy from this equation to see that (at one end of the spectrum) the wavelength of red light is longer and the frequency is less than for violet light (at the other end of the spectrum) where the wavelength is shorter and the frequency greater. For children of this age level the mathematical equation may becloud comprehension more than it clarifies; however, a more interested child may desire to probe more deeply than the relationship of wavelengths to an inch (page 283). Children learn that wavelengths of light are very, very short.

The range of perception for wavelengths is less for persons than for some insects. Persons who cannot perceive wavelengths in the red and green bands of the spectrum are termed color-blind.

The particle theory explains some behaviors of light in terms of tiny particles called photons. At present, the evidence is that both theories are needed to explain all the behaviors of light. Later evidence may show that one theory is better than the other.

Analyzing a Star's Light

Remembering what a prism does to light, children learn how a star's light is used to determine the elements of which it is made. By making flame tests of a few elements, they learn something of the technique of astronomers who fingerprint the elements in the stars through the prisms of a spectroscope. Combining the spectroscope with a camera, astronomers discover that stars are made of elements like those on the Earth, but that most of their matter is mainly hydrogen and helium. The *fusion* of hydrogen into helium (actually the fusion of the hydrogen nuclei) releases the tremendous energy poured out by the Sun.

The Distances in Space

Distances in space are so great that usual measures of distance are useless. Astronomers, therefore, use the light-year, a unit of distance equal to that traveled by light in one year.

Since light travels so fast and across such distances, light from the stars shows them as they were, not as they are. Radio signals and radio astronomy have provided a new tool for determining time and dimensions in space. Thus, we see stars only as they were when the light left them years ago on its journey to our eyes.

These are the main ideas that are introduced in this unit.

SUPPLEMENTARY AIDS

Films

All films and filmstrips are in full color. Names and addresses of publishers and suppliers are given on page F–25.

How We Explore Space ($16\frac{1}{2}$ min.), F.A. Introduces the instruments astronomers use and the methods by which they obtain information about the objects in space. Contains motion pictures of planets. (Intermediate)

All About Light (11 min.), Cenco, 1963. Explains how light travels, the speed of light, natural light from the Sun, and artificial light as well as the separation of light waves into a spectrum. (Intermediate, Junior High)

What Is Space? (11 min.), E.B.F. A trip through space by rocket ship conveys the tremendous extent of outer space. Space between Sun and Earth filled with heat and light and radio waves. Outer space distance is measured in terms of light-years. (Intermediate, Junior High)

How to Bend Light (11 min.), E.B.F. Proves that light travels in a straight line; explains reflection and refraction, and how light can be bent. Shows the ways in which lenses are used to magnify objects and focus an image. (Intermediate, Junior High)

Light and Color (14 min.), E.B.F. Experiments illustrate that light and color seem to be connected; that color depends on the ability of an object to absorb certain colors and to reflect other colors back to our eyes; that every element, when heated, has a characteristic set of colors—"color fingerprints." (Intermediate, Junior High)

Filmstrips

Astronomer at Work (42 frames), McGraw-Hill, 1957. Explains how astronomers search the skies with telescopes and the cameras make a record; shows how to make a simple telescope; spectroscope and its uses; light meter. (Intermediate)

Light (42 frames), McGraw-Hill, 1952. All light comes from a source. Explains reflected light, how light travels, refraction. Gives simple experiments using different lenses. (Intermediate)

Light and How It Travels (40 frames), Jam Handy, 1959. Sun is most important source of light. Explains transparence, translucence, shadows, reflection and refraction of light. (Intermediate)

Light and Color (49 frames), Jam Handy, 1959. Explains how different light waves are seen as different colors; spectrum. (Intermediate)

Man Becomes an Astronomer, Walt Disney (49 frames), E.B.F., 1959. Cartoon drawings show the many early beliefs and superstitions about the Moon. Might be used to show difference with present "scientific approach." (Intermediate)

Science Reading Table

Starred titles are especially recommended for their interest and content. Addresses of the publishers are on page F–24.

The First Book of Light by George Russell Harrison, Franklin Watts, 1962. Describes the relation of light waves to the radio-wave spectrum. The material on how a candle emits light helps to relate complex concepts and direct observation. An account of the development of arc, incandescent, and fluorescent lamps is included. (Advanced)

°*Exploring the Universe* by Roy A. Gallant, Doubleday, 1956. Following introductory material on the development of astronomy from early times to the present, the topics of stars, novae, meteors, comets, and the expanding universe are explored. The brief text is supplemented by excellent drawings. (Average)

Andy's Wonderful Telescope by G. Warren Schloat, Jr. Scribner's, 1958. The principles of reflecting and refracting telescopes are pictorially explained. Brief explanations of basic concepts are enhanced by photographs and analogies. Describes the solar system and constellations. (Average)

Light and Color by Frederick Healey, John Day, 1962. Describes the basic physical properties of visible light. Experiments and illustrations develop understanding of reflection, refraction, color blending, and other light phenomena. The importance of the Sun as man's source of energy is emphasized. (Average)

°*Fun and Experiments with Light* by Mae and Ira Freeman, Random House, 1963. Less capable readers will find the book useful for selected or assigned sections to improve competence in understanding directions for investigation. Thirty-three investigations to help children study the properties and characteristics of light are described with explicit directions and photographs. Most of the materals needed for the investigations can be found at home or at school. (Average)

Telescopes and Observatories by Patrick Moore, John Day, 1962. Description of the smallest hand telescopes to the largest observatory instruments is included. Optical principles are explained with narrative supplemented by diagrams. Instructions for the reader to make his own telescope are given in simple terms. (Average)

Our Wonderful Eyes by John Perry, McGraw-Hill, 1955. Structure and function of the eye are described with interesting information about light and seeing. Optical illusions and material on care of the eyes. (Average)

What Is Electronic Communication? by Daniel Q. Posin, Benefic Press, 1961. A survey treatment of the subject, including information on the flow of electrons, the use of electronics in radio, television, and other methods of communication. Simple diagrams explain a complicated subject. (Average)

▶ INTRODUCING THE UNIT

Reading of the opening two pages of the unit with the children should start them thinking. How do we know that we never see bodies in space as they are but as they were? Is this not an astonishing idea? What makes stars shine? There must be some source of energy since we can see the Sun but we cannot see the Moon unless light from the Sun strikes it. How do we find out about the stars? Children may raise these and other questions which will help guide the work of this unit.

Section 1: THE BIG EYE

Children are given opportunity to understand the work of an important tool used in studying bodies in space.

(*Text pages 272–276*)

SUBCONCEPT

Component bodies of the universe are in constant motion.

Processes emphasized

Investigation (with design of experiment

Observation

Analysis

Hypothesizing

Theorizing

Equipment and Materials

. . . cardboard tubes of different lengths and diameters

Introducing the Concept

Ask the children to imagine that the mailing tube you are holding is a telescope. One child may look through it at a classmate across the room. If the tube is supported or steadied, any motion will be more apparent. When the other child is in line of sight, what happens if the telescope is moved slightly? What happens when the child being viewed moves? Repeat, focusing on some distant object visible through the window. Do stars move or stand still? Are we moving as we stand watching stars? Why is it hard to keep a star or group of stars in view?

Can you reason out two motions which must be used in operating every modern telescope? Would the telescope move faster or slower in viewing the stars nearer you? (Your mailing tube investigations and your text can tell you.)

Developing the Concept

Children discover how mirrors collect light.

A mirror, catcher of light. Looking at stars through binoculars magnifies them, does it not? Why do modern telescopes not only magnify, but em-

Equipment and Materials

... collection of hand mirrors, square, round, rectangular

ploy mirrors? (To collect light.) Does the size of a mirror have anything to do with the amount of light collected? Working with a variety of mirrors helps the children see that it does. How big are modern telescope mirrors? To give a sense of size of the great 200-inch mirror at Palomar, let them measure the small mirrors, then measure off 17 feet in the hall or on the playground. For clearer visualization, children could take turns lining up to help them imagine how big a 17-foot mirror must be.

Light collected by a curved mirror can be brought to a focus and magnified by a lens.

Curved surfaces and focus. Why is the great Hale mirror curved? To answer the question children may first need to find the focus of the more familiar curved lens, such as that in a magnifying glass or the front of a flashlight. On a sunny day, or with an electric bulb, they can see the rays brought to a focus on the side beyond the lens.

Equipment and Materials

... shaving mirrors of different sizes or concave hand lenses

... magnifying glass

... flat mirror

Next, let them work with curved mirrors and flat mirrors. Encourage them to make predictions about the focus. Where will it be? (In front of the mirror.) Which mirror is more likely to bring light to a focus? (Curved.) Why? (The light will be reflected to a point.) Demonstrate by shining a light at a mirror and moving a sheet of white paper in front of the mirror to catch the reflection. By moving the paper back or forth, you can focus the light from the curved mirror and also show the reflected glare from a flat mirror. Children relate this collecting of light to the functioning of the Hale telescope as they read the text of this section.

A telescope mirror serves to collect light.

No picture without light. Do you like to take pictures? What do you need? (Camera, film, light.) Suppose there is not enough light. What can you do? (Use floodlight, flash bulbs.) In review of the use of a microscope, how do you increase the light under the slide? (By tipping the mirror.) Some microscopes have a mirror with both a flat and a curved surface. Predict which surface will afford the most light. Why?

What often happens when you take pictures of objects that are moving too fast? (They are blurred.) What happens if you move the camera while taking a snapshot? (The picture is blurred.) What two ways can you think of to stop blurring? (Keep the camera steady and move it to follow the moving object.) Now, imagine that *you* are moving fast and wish to take a picture of an object that is not moving or moving only very slowly. What must you do? (Same answer.) You are—on Earth—traveling around the Sun at a speed of over 66,000 miles per hour and you are also traveling with the Earth's rotation as it turns on its axis once every twenty-four hours. You are whizzing by the stars which seem to be standing still. Predict what you must do to get a clear picture of a star. Those children who have a camera may test out their prediction by performing the investigation on text page 275.

If children do not have a camera, the effect can be shown easily by using mailing tubes or rolled sheets of paper as you did when introducing the concept. Draw several stars in line across the chalkboard. Let each child locate one star in the center of his tube and lean to the side without moving the tube. The star will move across the open end and disappear. What must the astronomer do to get a clear picture with a telescope camera? (Move the telescope.) What two motions must a telescope be able to make? (It must be moved for focusing and for keeping the object fixed in the field of the telescope.) How are these motions made in an observatory? Children are now ready to read and discuss "The Big Eye at Work" on page 274.

Extending the Concept

Big and little dishes. Since the 1930's, astronomers have been using a new tool, the radio telescope, which gives a much wider view of the universe. It uses radio signals that travel at the speed of light. What can you find out about radio astronomy? How large is the dish-shaped antenna at Jodrell Bank, England; in the Pyrenees; in Puerto Rico; in Greenbank, West Virginia? The radio telescope at Stanford University bounces an electric signal off the surface of the sun, waits 15 minutes before turning on the receiver. Can you explain the time lag? (Clues—How fast do radio waves travel? How far is the Sun?) For further details and fascinating information, read *The Big Dish,* by Roger Piper, Harcourt, Brace & World, 1963.

Equipment and Materials

. . . globe or world map

The work of an astronomer. What do astronomers watch for in their photographic records? If they are studying a distant galaxy and a planet is in orbit in front of it, what would you predict the planet's path would show on the photograph? (A blurred trail.) Why? Do astronomers usually study the sky at the same time in the United States as in South America? As in England? As in South Africa? A globe or a map will help answer this question. You may wish to locate the world's great observatories on a world map. What determines the location of an observatory?

(Text pages 274, 276)

Reviewing the Concept

Before You Go On. 1. It collects much more light and then magnifies the images of the light. 2. No. It would be unable to bring the light to a focus, or collect so much light.

(Text pages 276–281)

Section 2: THE LIGHT WE SEE

SUBCONCEPT

Light travels in straight lines; it can be broken into a spectrum of colors as it passes through a prism.

Children view the everyday phenomenon of light with deepening understanding and interest.

Introducing the Concept

How does light work? How many kinds of light are there? These questions stimulate thinking about a phenomenon in their environment which children largely take for granted. Ask a child to go out of the room and return. The door should remain open. Did you hear the child return before you saw him? Why? Does your observation tell you anything about light? What can the rear-view mirror of a car tell you about light? (Light is reflected.)

Processes emphasized

- Observation
- Analysis of reading
- Measurement
- Investigation (with design of experiment)

Processes emphasized

Prediction
Hypothesizing and theorizing
Model making

What can a ball and light both do? How can this common characteristic be put to use? What is colored light? Is there any kind of light you cannot see?

Developing the Concept

Note. Three ideas about light may easily be developed before the children read their textbook: its straight-line motion, reflection, and how prisms work. Or you may develop the ideas concurrently with the reading.

Children discover that light moves in straight line.

Equipment and Materials

- . . . loud ticking watch or clock
- . . . 1′–2′ flexible tubing

"Straight-lined" light. If you hold a hose to one ear and cover the other ear, can you hear the clock tick? Try each ear. The activity can offer an informal check upon children whose behavior suggests partial or total hearing loss. Any evidence you uncover should be referred to the school doctor. Can you hear the ticking if you bend the hose? Can you see the clock through the hose? (Not if the hose is bent.) What do these activities tell you about light? (It travels in a straight line.)

Light can be reflected by mirrors.

Equipment and Materials

- . . . ball
- . . . mirror
- . . . light source

Does light bounce like a ball? Bouncing a ball off the wall differs from bouncing light off a mirror in an important respect. Encourage children, by their own observations, to conclude that the path of a ball is curved (due to gravitational force), but that light bounces in straight lines. How does the illustration on page 277 in your textbook show that light travels in this manner? What other examples can you name? Distinguish between direct light from the Sun and reflected light from the Moon.

Can you make light turn a corner? (Yes.) Give all the examples you can think of. How does each example illustrate how light turns a corner? (Light is reflected.) How is this characteristic used—for example, in a submarine's periscope? In what other ways do we make use of the straight-line motion of light?

Lenses and prisms can change the direction of light.

Equipment and Materials

- . . . hand lens
- . . . prism or 3 microscope slides

(See also the Teacher's Manual for *Classroom Laboratory 5*.)

What does a triangular piece of glass do to light? Ask this question as you display a prism. Inexpensive prisms from tank telescopes are often available at Army surplus stores. Fragmented prisms from chandeliers can often be found in antique shops. Or children can make crude prisms by taping together the ends of three microscope slides to form a triangle. What will a prism do? Children may reason that light should spread out. After their responses and reading of the text through page 277, encourage children to perform the investigation with a prism (text page 278).

Parts of the light spectrum are invisible; their existence can be inferred from their effects.

Infrared and ultraviolet. After children have finished reading the section, you may wish to try to duplicate Herschel's experiment by placing a thermometer next to the red end of a spectrum made by sunlight passing through a prism. It will be well to use two thermometers so that the rise in one thermometer can be compared with room temperature.

The prefixes *infra* (below) and *ultra* (beyond) may be confusing unless the prism is so set up that the red band is at the bottom as in the illustration on text page 278. Actually, *infra* refers to the frequency of light waves, i.e., the number that pass a given point in a given period of time, or the number of waves in a given distance. Looking ahead and referring to the table on page 283, children can see that *infra*red is *below* 25,000 waves to the inch and that *ultra*violet is *beyond* 70,000 waves to the inch.

Extending the Concept

An activity with colored light. All children love color and its use in art lessons. The art teacher might be invited as a resource consultant to demonstrate the mixing of colored lights. Encourage the children first to make a colored drawing of the spectrum from observation. Can the light spectrum be used as a guide to the mixing of colors? The art teacher may be willing to show how the mixing of light differs from the mixing of pigments.

Equipment and Materials

- . . . 2 prisms
- . . . rectangular tank
- . . . wooden stick
- . . . jar
- . . . coin
- . . . cup

Can the colors in a prism be combined to make white light? Encourage guesses. Then allow children to work with two prisms to see if they can find a combination that will recombine the colors.

Can you make a prism from water? Try moving a rectangular tank in the light so that the sun shines on it and a spectrum is formed. Encourage the children to explain in terms of the shape of the part of the tank through which the light passes.

In what other ways can the direction of light be changed? Set a stick in a jar of water. Why does the stick appear broken and also bent? An interested child may investigate in an encyclopedia. The phenomenon is refraction. The water—or any other medium—slows the speed of light and changes the direction of its component waves. An interesting trick will whet interest. Place a coin in the bottom of a cup or other opaque container. Stand back just far enough so that the coin cannot be seen over the rim. Ask someone to pour water into the cup. Why do you soon see the coin? This is explained by the difference in which light is reflected (and refracted) in a medium other than air. Science "experiment" books contain other interesting investigations and activities that depend on the straight-line travel of light from a direct or a reflecting source.

Herschel's hypothesis. Recall how Joan Waterman went about her investigation in Unit Six. Can you state in your own words what Herschel's hypothesis might have been? Could you draw or diagram his experiment as you imagine it may have appeared? Why was Herschel's a true experiment?

(*Text pages 280–281*)

Reviewing the Concept

Before You Go On. A. 1. b 2. b 3. a 4. a 5. a

Using What You Know. 1. Film sensitive to infrared light given off in the dark was used. 2. The sunlight came through a corner of the tank as if through a prism.

(*Text pages 281–284*)

SUBCONCEPT

The behavior of light may be explained as the motion of waves through space.

Processes emphasized

Theorizing
Measurement
Model making

Section 3: LIGHT AS WAVES

Children consider and analyze evidence supporting the wave theory of light.

Introducing the Concept

Fasten one end of a rope or length of clothesline to a doorknob or other stationary point. Hold the rope loosely extended and give the free end a good shake. The children watch carefully for the wave motion which runs along the rope. Repeat, asking them to watch for the top (crest), then the bottom (trough) of each wave. How do the waves seem to move? (Regularly and at the same speed.) Shake the rope gently, then vigorously. What differences do you see in the "parade of waves" set up, in their shape and speed? (Smaller waves moving faster.) There is a theory that light travels in waves. What would you predict about the shape and speed of light waves as compared to the waves in the clothesline? If you measured the length of the clothesline waves from crest to crest, how do you think they would compare with light waves?

How long are light waves? How fast do these waves move? How can we measure them?

Children infer that the number of waves is related to the length of the wave.

Equipment and Materials

. . . dish pan or aquarium
. . . food coloring

Developing the Concept

Number of waves and wavelength. When the children have read the section, let them observe water waves, as their textbook suggests. Coloring the water will aid visibility. If differently shaped objects are dipped in water, do the wave shapes differ? What differences do you see if you dip objects quickly instead of slowly? Are the wavelengths shorter, as they were when the clothesline was shaken more rapidly?

Are there more waves when the wavelengths are shorter? What seems to be a relationship between the number of waves and the wavelength? (The more waves there are, the shorter they are; the fewer the waves, the longer they are.)

Children gain an understanding of the shortness of wavelengths of light.

How short can a wavelength be? How much is 1/30,000 of an inch? How many marks can you crowd into an inch line on the chalkboard or on paper? Can you make a diagram on the board or on paper to show what is meant by wavelength? (An even, wavy line marked from crest to crest.)

If the children have drawn the color spectrum band as suggested in Section 2, encourage them to add the wavelengths from the data in their text. Of course the wavelength must be expressed as a fractional part of an inch. Since the figures give an average number, the midpoint of the band will, of course, be that figure. You may wish to plan for a large scale model of the spectrum on the chalkboard. If you have a meter stick marked off into centimeters, let 70 centimeters equal the total length of spectrum, and the divisions can be read directly from the stick. If you have only a yardstick and allow, say, 30 inches for the total spectrum, children will have to practice their knowledge of fractions. For example, the green band would be marked off at 48/70 of 30 inches. Discuss what scales should be used, and allow children to proceed.

Do we all see alike? Which wavelengths of light in the spectrum are invisible? Are these longer or shorter than the wavelengths we can see as color? (Ultraviolet shorter, infrared longer.) Which have more wavelengths to the inch? (Ultraviolet more, infrared fewer.) Which wavelengths of light cannot be seen as colors if one is color blind?

By way of review, you may wish to ask children: to draw and describe "a parade of waves"; to explain the difficulties of measuring red light with a ruler; to explain the motion of light when they turn on a lamp.

Children relate wavelength to the color spectrum.

Equipment and Materials

. . . charts for testing color blindness (if available through school health personnel or optician)

Extending the Concept

Color blindness. The school nurse or doctor or local oculist can be a useful source of information about color blindness. Since the condition is more prevalent among men, encourage a boy to gather information. For example, how does color blindness affect response to traffic signals?

A bee's eye view of life. Children who have shown interest in insects may, with the cooperation of the school librarian, investigate studies on the vision of bees and other animals. The references may require upper-level reading ability.

What are filters for light? Children may have seen spotlights casting different colors or their parents using a filter on a camera. What do filters do? An interested child may investigate how a pane of glass of one color subtracts the wavelengths of other colors from a spectrum and allows mainly the wavelength of that color to go through. They can easily demonstrate by setting up a prism as in Section 2, casting the spectrum on a sheet of white paper, and then inserting the color pane between the prism and the white-paper screen.

Reviewing the Concept

(Text page 284)

Before You Go On. 1. a 2. b 3. b 4. a 5. b

Using What You Know. 1., 2. Blue, green, yellow, red. Blue has more waves in an inch than green, yellow, and red in that order; hence, blue has shorter wavelengths than green, yellow, red in the same order.

Section 4: LIGHT AS PARTICLES

(Text pages 285–287)

SUBCONCEPT

Light behaves at times as particles, and at times as waves.

Children examine some evidence that light behaves as if it were made up of particles and compare it with evidence that light behaves as waves.

Introducing the Concept

Borrow a light meter from a photographic supply shop or from a camera enthusiast if you do not have one of your own. Since a light meter is a

Processes emphasized

Investigation (with design of experiment)
Measurement
Hypothesizing
Theorizing
Prediction
Model making

delicate instrument, you may prefer that children do not handle it. Make it possible for them to see how the needle changes position for different intensities of light. What makes the meter work? What is the source of the energy? (Light.) Recall that in boiling water it is the speed of the molecules (matter) that gives the water its heat and that particles of matter (in fuels) give a rocket the push it needs. Do you think energy is needed to make the needle on the light meter move? Do you think some kind of particle is needed to make it move?

Can light be made of particles instead of waves? Can it be both? What is your hypothesis? Review the meaning of hypothesis if necessary (page 230).

Developing the Concept

Children examine an example of light behaving as particles rather than as waves (electrical energy).

How does a light meter work? After children have read the section, continue discussion of the light meter. Into what kind of energy is light being changed? The child's text tells how electrons are given off when light strikes selenium. You may wish to discuss electrons more fully in relation to the atom whose nucleus was studied earlier (Unit One, page 27). Every atom has protons and neutrons in its nucleus, but the nucleus also has electrons moving around it. Electrons, when they are made to move through wires, make an electric current. The electrons that come off the selenium when light strikes it move, causing the needle to move. The more electrons the selenium gives off, the farther the needle moves. The light meter tells you how much, how strong, the light is. Why is the wave theory of light not enough to explain how a light meter works?

What happens when we produce light energy? Hold your hand near a lighted electric bulb. Your hand feels warm, doesn't it? When a green plant makes food, photosynthesis takes place. When you take a photograph, a change takes place in the film. What is the name for a particle of light? (Photon.) To what kind of energy do the words *photon, photo*synthesis, and *photo*graphy refer? (Light.) Encourage children to make cartoon drawings to show how photons behave when they turn on a lamp or a flashlight or go out into the sunlight.

Children compare the two theories of light and become aware that more evidence is needed.

What do the two theories of light tell us? Recall how light moves through and is spread out by a prism. What does this behavior seem to indicate? (Light can be explained as consisting of waves.) What does the particle theory seem to indicate? (Light, by setting matter in motion, as electrons or molecules, seems to consist of particles.) Do you think one theory is better than the other? A panel of children may debate this question, while the rest of the class listens to challenge them for any statements quoted erroneously from their textbook. Why don't scientists agree on which theory is better? (Not enough evidence.) What other theories that await further evidence have you studied this year? (e.g., George Darwin's origin of the Moon; how the universe was formed.)

Extending the Concept

How do photoelectric cells work? How does the "electric eye" (a photoelectric cell) work in opening a door? (When the light beam is interrupted, the electric current goes off, and a spring or other mechanical means operates the door.) You may wish to create interest by telling the story of the housewife who saw the garage door, equipped with an electric eye, opening and closing as swallows flew in and out. Why? The photographer's light meter contains a photoelectric cell. How does an automatic light meter built into certain models of cameras work to set the shutter? Airplane beacons may turn on automatically as daylight fades. How can you explain this? The answers to these and other uses of the phototelectric cell may be the subject of an interesting report.

(*Text pages 286–287*)

Reviewing the Concept

Before You Go On. 1. a 2. b 3. a 4. b

Using What You Know. 1. The wave theory best explains a; the particle theory best explains b. 2. The Law of Universal Gravitation; the Laws of Motion.

Section 5: WHAT LIGHT FROM THE STARS SHOWS

(*Text pages 288–293*)

SUBCONCEPT
The light from the stars enables us to determine their composition and their temperature.

Children begin to understand how study of the spectrum of light from the stars helps us determine how hot the stars are and what they are made of. They find that stars differ in their composition and state.

Processes emphasized

Investigation
Analysis of data
Hypothesizing
Theorizing
Prediction

Equipment and Materials

. . . candle or alcohol lamp
. . . paper clip or many-stranded picture wire
. . . pliers or kitchen tongs

Introducing the Concept

How hot is hot? Be sure to use an asbestos sheet or have a container of water at hand. As you demonstrate, point out safety precautions. Examine the flame of a candle or, better yet, an alcohol lamp. Place it in a corner or in the shadow of a carton. What are the colors of the flame? (Blue, orange, yellow.) Which part is the hottest? How can we tell? Produce the materials listed. How can we use them to tell us which part is hottest?

Unbend a paper clip, or use a piece of many-stranded picture wire. Hold one end with a pair of pliers, and place the other in the flame. As the wire grows hotter, it grows red, then orange. If the candle gives off enough heat, the wire will become white hot.

Relate what the children are seeing to everyday objects such as wires in toasters or electric heaters, electric stove coils, light-bulb filaments. Ask: From the color of the glow, which is hotter?

How is the color of distant stars related to their temperatures? Can we find out what the stars are made of by studying the light from them?

Developing the Concept

How to explore the sky without ever leaving Earth. Why do the police fingerprint persons who have committed a crime? Why do many hospitals

Children deduce that different elements produce different flame colors.

Equipment and Materials

. . . stamp pad
. . . cotton
. . . boric acid or box of borax
. . . swab sticks
. . . Sterno or alcohol lamp

(See also text page 289 and the Teacher's Manual for *Classroom Laboratory* 5.)

take a footprint of every new baby? Is your fingerprint different from that of others? A local police officer might be willing to give a brief demonstration of fingerprinting, although the technique is relatively simple and can be demonstrated by an interested child.

Do you think it is possible to take a "fingerprint" of the 90 or more elements of which the Earth is made? What equipment would be needed? (Flame and prism.) What must be done to the element boron so that we may see its flame color? (Heat it until it becomes a gas.) Roll a bit of cotton around an applicator stick. Dip into a solution of boric acid or household borax. Hold over flame until the solution becomes gaseous and the greenish cast is observed. Children may now start reading the text and performing the investigation (text page 289), under your close supervision. You may wish to handle the burner yourself, allowing the children to prepare the substances. For other flame tests of common substances, see *A Sourcebook for Elementary Science*, pages 198–199.

After children have read the paragraphs under "Fingerprints of the Elements" (text pages 288 and 290), ask: What else is needed to see the fingerprints of boron? (A spectroscope, i.e., a prism for spreading the light, and lenses for viewing.) The flame colors of each element, when spread out by a prism, produce characteristic and individual patterns of lines and colors (bright-line spectrum). Can you think why? (The colors of the flame are broken up into different wavelengths of light.) You may wish to have the children relate the colors to wavelength by reference to their work with the spectrum in Section 3. The science of spectroscopy began with flame tests of substances in the chemist's laboratory. Can you suggest how chemists have aided astronomers in exploring the sky?

Children become aware of the enormous temperatures of stars.

How does the Sun tell us about the other stars? What is the hottest temperature you know from experience? What is the highest temperature in your home? Children discover, by comparing the top range of home wall and oven thermometers, for example, that these top temperatures are very little compared to that of the surface of the Sun (10,000° F.) Other temperatures you may wish to cite for comparison are: highest outdoor temperature recorded on Earth, 136°F.; iron melts at about 1500°F. and turns to a gas at 3,000° F.; temperature inside the Sun is as high as 10,000,000° F.

Beginning a class chart of high temperatures gives children some basis for appreciating the Sun's surface heat. Where does all this energy come from? (The *fusion* of hydrogen atoms into helium.) Why does this reaction take place on the Sun and not on Earth? (Great heat.) By building nuclear reactors, man has split the nucleus of uranium atoms and produced other elements and great heat. We call this nuclear *fission*. The 100,000,000° F. heat from nuclear fission is needed to produce fusion. Fusion is the energy-producing process of all the stars.

How does the great heat of the Sun and stars tell the astronomer which elements can be found on them? (All elements as glowing gases will give off light.) How does an astronomer find out about these elements? (He uses a spectroscope.) Why does he attach a camera to his spectroscope? (To get a permanent record for study and comparison.)

Extending the Concept

Color spectrum and bright-line spectrum. Compare the color spectrum of visible light to the bright-line spectrum produced by elements. Children will need to consult references. Reproduce by colored diagrams some of the simpler bright-line spectrums produced by common elements.

Color of stars. The hottest stars have a bluish-white light. Our Sun is medium hot. Rigel, 14,000 times brighter than our Sun, is blue-white. Betelgeuse is a red giant, one of the biggest stars known. Capella is yellow like our Sun. Aldebaran is orange, cooler than our Sun. Children will enjoy grouping stars by their color and relating the color to the temperatures.

STAR COLOR AND APPROXIMATE TEMPERATURE

Star	Color	Surface temperature
Rigel	blue-white	above 36,000° F.
Procyon	yellow-white	13,500° F.
Sun	yellow	10,000° F.
Arcturus	orange	7,500° F.
Antares	red	5,500° F.

Do these data conflict with the text idea that the spectrum is determined by the star's composition? (No. The spectrum of a star reveals its composition; the visible color of a star reveals its temperature.)

Sunlight and moonlight. Why would it be impossible to get a spectrum by letting moonlight go through a prism? (Only direct light from a source of glowing gases will produce a spectrum; moonlight is reflected from cold, solid matter. What other bodies in space are visible only from *reflected* light? (Planets, satellites.) Can you now explain why men must visit the Moon, only 240,000 miles away, or Mars, 48,000,000 miles away, but not the Sun, 93,000,000 miles away, in order to know which elements they are made of?

Spectroscopes and telescopes. How are spectroscopes and telescopes alike? Different? How does a spectroscope work? For details on making a mailing tube spectroscope and on diffraction gratings, see *A Sourcebook for Elementary Science*, page 264.

(*Text pages 292–293*)

Reviewing the Concept

Before You Go On. 1. a 2. b 3. a 4. a 5. a

Using What You Know. 1. A planet; 1 percent hydrogen is not enough for fusion. 2. It is changed to energy.

UNIT SEVEN

BUILDING BLOCKS OF THE STARS

We never see the Sun as it is. Never do we see the Moon or the stars as they are. We see them as they *were*.

We see the Moon as it was about one second ago. We see the Sun as it was about eight minutes ago. We see the nearest star as it was about four years ago.

When we look at the night sky, we are looking at the past.

How can this be? The answer lies in another question. What do we see when we look at the stars? One way to begin to answer this question is to visit an astronomer and explore space with him. Let's study the stars and the building blocks that stars are made of. Let's go to Mount Palomar and look through the "Big Eye."

■

1. The Big Eye

High on top of Mount Palomar in California is the Big Eye—the Hale telescope. See the picture marked with a square. ■ It is the world's largest telescope. Let's visit it on a cold winter night.

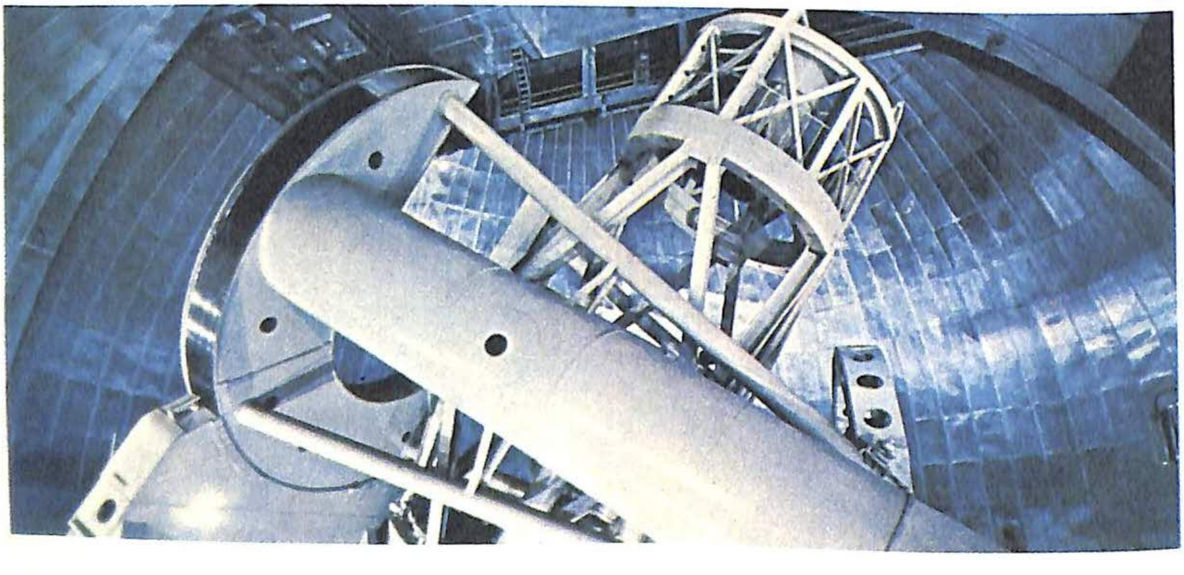
Our astronomer friend greets us dressed in an electrically heated suit. He gives the telescope engineer the plan for the night's work. The telescope is moved about by machinery which the engineer controls.

The great telescope towers above us. ● To reach the cage where the observer sits, we enter a little elevator. It rises slowly. Seventy-five feet above the floor it stops. Carefully we step into the observer's cage.

In the Observer's Cage

We are near the top of the telescope, and inside it. We notice that the elevator is moving away. No, it is we who are moving, as the telescope swings smoothly into position. The astronomer turns some dials, puts his eye to an eyepiece, then beckons us to look in. We see the night sky, crowded with stars that we have never seen before! ▲

●



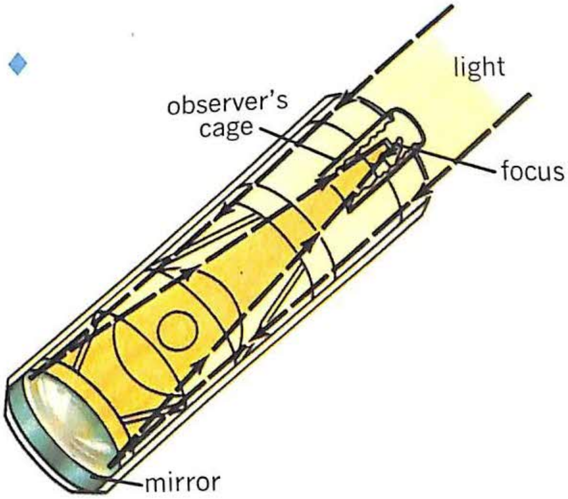
How does this happen? In the Hale telescope, light from the stars is collected by a huge mirror almost 17 feet across. Such a mirror can collect far more light from a distant star than your eye can. So the Hale telescope can "see" much fainter stars than your eye can see. It can see much farther out into the universe than any human eye.

This giant mirror is curved so that it brings the rays of light from a star to a point called the **focus,** as the diagram shows. ◆ If you were to hold a piece of paper at the focus, you would see an **image** of the star on the paper. However, the image would be very small indeed. The eyepiece magnifies the image of the star.

When we look into the eyepiece, we see many stars we could not see before because the huge mirror collects much more light than the eye.

Strangely enough, the astronomer does not spend much time looking into an eyepiece. He has a better way of studying the stars. He takes photographs of them.

The Big Eye is really a collector of light for a camera. The camera film is



a better recorder of light than the astronomer's eye, in many ways. So the astronomer doesn't study the stars directly. He studies photographs of the stars. When he, or his assistant, is in the observer's cage, he is taking photographs of the stars most of the time.

Taking photographs of stars isn't easy. The astronomer asks to have the Big Eye pointed at a certain bit of the sky. The stars he wants to study are in that bit of sky. To photograph those stars, the telescope must stay pointed at them—sometimes for several hours. The Earth is moving, of course. It is turning on its **axis**, the imaginary line around which it spins. To stay pointed at those stars, the telescope must keep moving. The engineer controls the machinery that keeps the Big Eye, all 500 tons of it, pointed at the stars.

What would happen if the telescope didn't move? See for yourself. Try the investigation on the opposite page.

The Big Eye at Work

If the Earth were standing still, a camera pointed at the night sky would record a point of light for each star. But the Earth turns on its axis, and its axis is pointed at the North Star. So the stars appear to circle around the North Star when the camera is fixed to the Earth. On Mount Palomar, the machinery of the Big Eye keeps the telescope and its camera moving and pointing at the same star.

The Big Eye is a giant camera. Sometimes colored film is used, but for much of the work, black-and-white film does the job. When the light from a star is very faint, the film may be exposed for hours.

When the film is developed, the astronomer's real work begins. He studies the photographs. Through them the astronomer reaches out into the great distances beyond the Earth, beyond our solar system, beyond our galaxy. The Hale telescope reaches farther than any other telescope.

What does the Big Eye detect in the far out reaches of space? Before we can understand what the telescope shows us, we must know more about light. What is light? To learn more about it, we shall bounce light off mirrors, send it around corners, and even break it up.

BEFORE YOU GO ON

1. You can see many more stars with the Hale telescope than without it. Why?

2. Would the Hale telescope work without a mirror? Explain your answer.

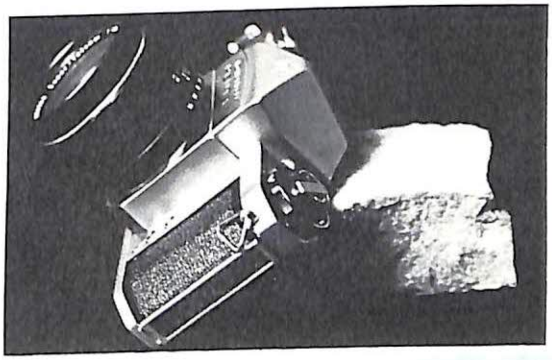
AN INVESTIGATION into Why a Telescope Must Move

Needed: a clear, moonless night, a camera, black-and-white film

Set up the camera so that it is pointed at the North Star. (If you are not sure which star is the North Star, see page 297.) If the lens opening is adjustable, use the smallest opening. This will keep down stray sky light. Set the shutter for a time exposure. Open the shutter and leave it open for 3 or 4 hours.■ Then close the shutter and remove the camera.

When the film is developed, you may see a photograph like this.● The lines which seem to be parts of circles are the tracks of stars. As the Earth rotates, the camera turns with it. The light of each star is recorded on the film as a long, curved streak.

Additional Investigation: How would the camera have to be moved to get an unstreaked picture of the stars?



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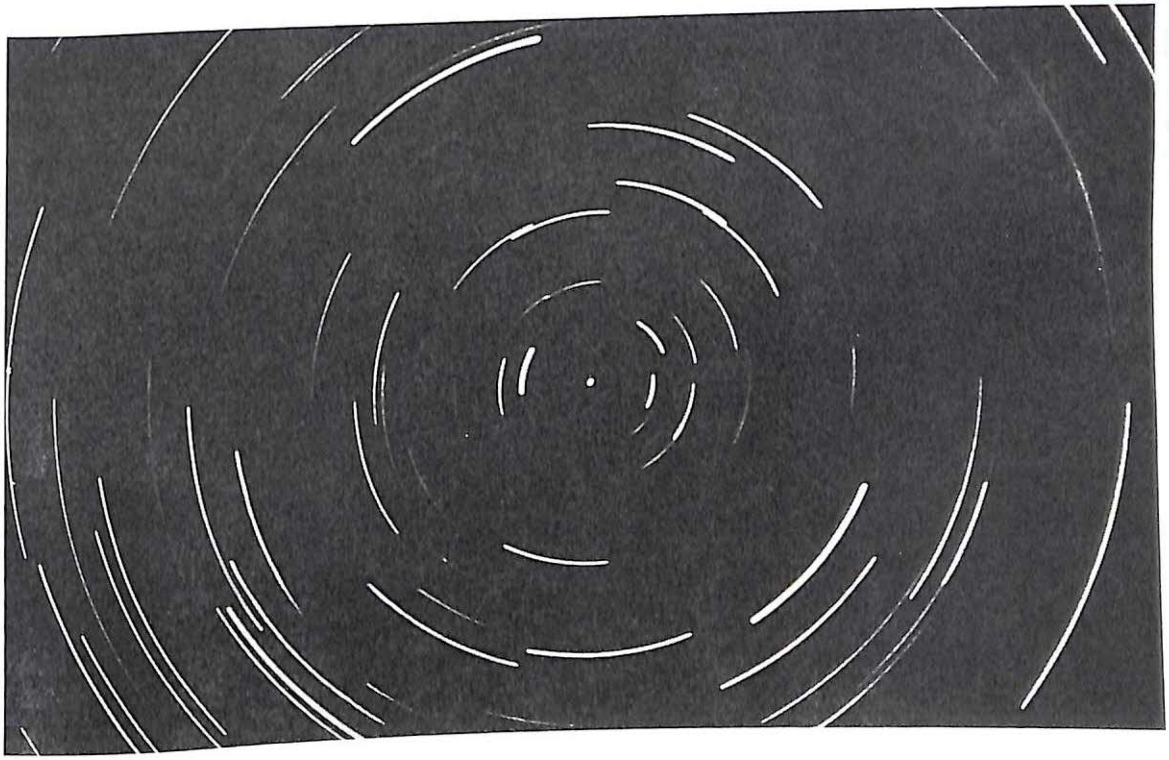


●

ON YOUR OWN Get a magnifying lens. Look at a small object, such as a penny, through the lens, keeping your eye close to the lens. Hold the lens close to the penny, then move it farther away. Does the lens magnify the penny more, or less, as it is moved away?

Can the lens magnify the penny as much as you please? Or is there a limit to its magnifying power?

The eyepiece of a telescope magnifies in the same way.

2. The Light We See

It might not seem so at first, but this picture points out something important about light. ■

The girl can *hear* the tuba. But she can't *see* it. Why is this so? It is because sound can travel around a corner. Light can't travel around a corner. Light travels in a straight line.

Suppose that you make a long tube out of newspaper. You will be able to look through it so long as the tube is straight. But bend the tube a bit and you will no longer be able to see through it. ● Why? Because light travels in a straight line. It does not turn the corner in the tube.

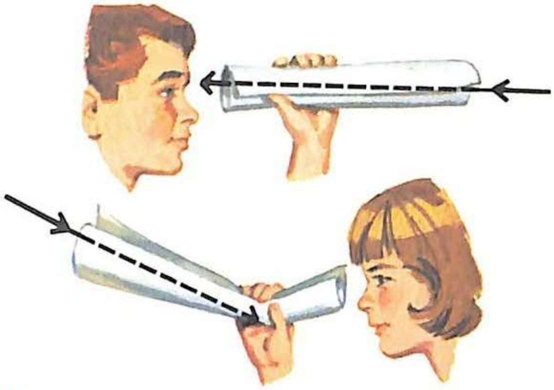
■

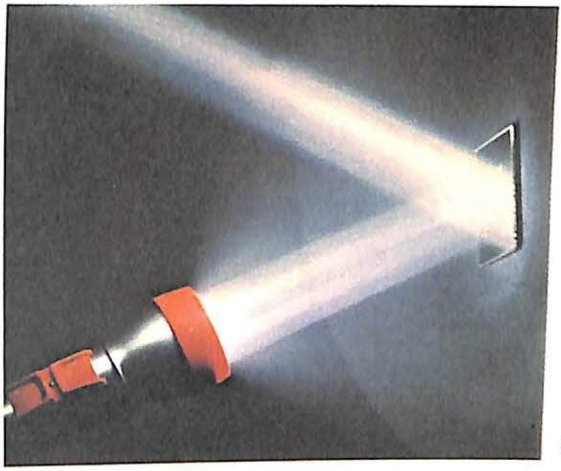
Put the bent tube to your ear. You will still be able to hear through it. A sound going into the bent tube can turn the corner. Light can't turn the corner. **Light travels in a straight line.**

The Way Light Travels

Light doesn't travel around corners. There is a way, however, of seeing around a corner by using a mirror. ▲ Perhaps you have already tried this. How does the mirror work? Does it bend the light, so that the light curves around the corner?

The mirror does not bend light. The light that hits the mirror and goes off in another direction is still traveling in straight lines. ◆ Light *bounces off* the mirror, rather like a ball bouncing off a wall. When light bounces off something, we say that the light is **reflected.** A mirror reflects light.

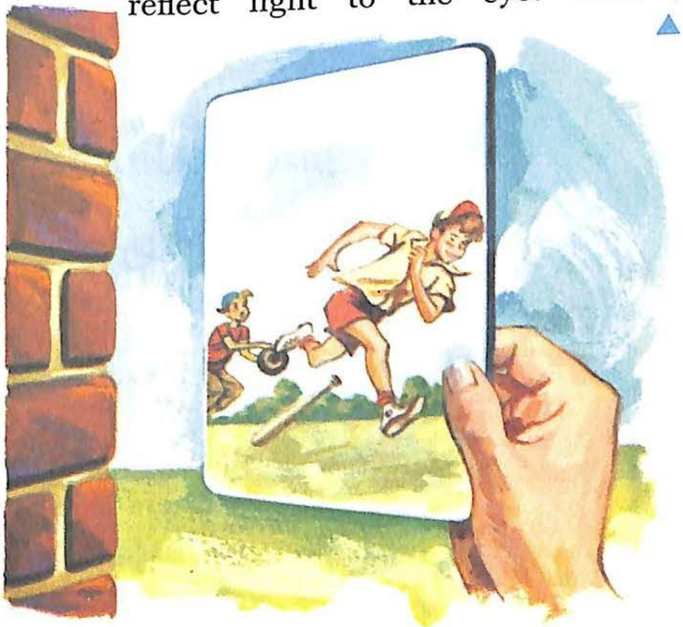


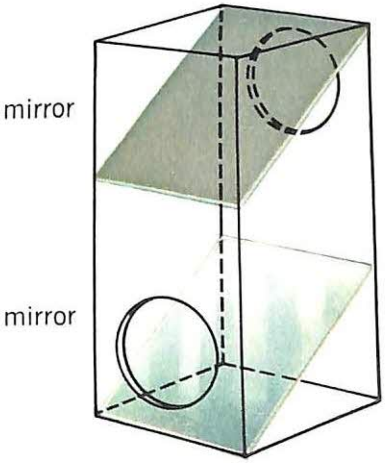


With a mirror, then, you can reflect light around a corner. Or you can see behind you, as an automobile driver does with the rear-view mirror.

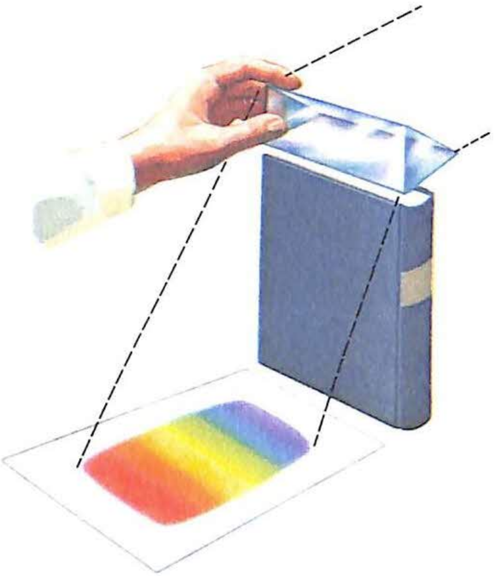
Here is a kind of periscope (per′ə-skōp) that you can make.★ Use a cardboard tube, or milk cartons fitted together, to hold the mirrors. The periscope can be used to see over the heads of a crowd, or to look around a corner. Do you see how the mirrors reflect light to the eye? Notice, though, that the light reflected from a mirror still travels in a straight line.

Light can be reflected. However, there is something else that can be done with light. By doing it, scientists have learned much, not only about light, but about the stars. For example, there is a piece of glass, shaped like a triangle called a **prism** (priz′əm). See for yourself what a prism can do to light. Try the investigation on the next page.





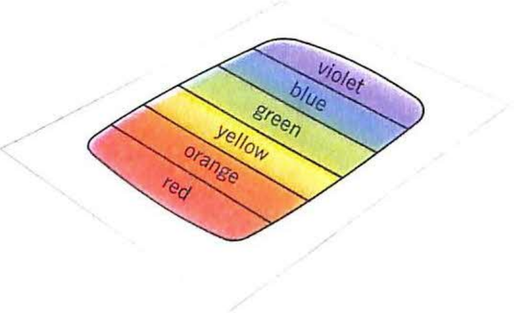
AN INVESTIGATION into What a Prism Does to Sunlight



■

Needed: a glass prism, a book, a sheet of white paper, a pencil, sunlight

Stand the book on end in the sunlight so that it casts a shadow.■ Place the sheet of white paper in the shadow. Now hold the prism just above the book, as shown. Turn the prism slowly, until a patch of colored light appears on the paper.



●

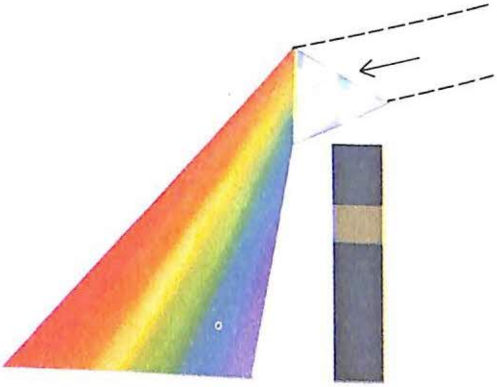
Observe that the colors are in bands. Can you name the colors? While you hold the prism steady, have a partner outline the bands of color on the paper with a pencil. Label the colors.● Are the bands all the same width?

Here is the path of the sunlight into the prism. Follow it down to the paper, by putting a finger in the light.

What color is the light entering the prism? What does the prism do to the sunlight?

Additional Investigation: Beginning with red, what is the order of the colors? Can you change the order by turning the prism, or in some other way?

What do you think sun glasses do to light? Do they affect some colors more than others? Can you use the prism to test your hypothesis?



▲

The Spectrum

White light from the Sun enters a glass prism. When it comes out, the light is no longer white. It is light of different colors. It forms a band of colors in this order: red, orange, yellow, green, blue, and violet.

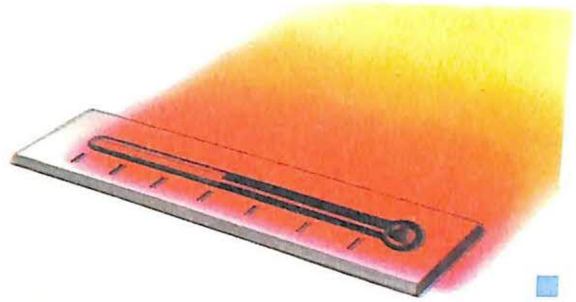
The colored band formed when light passes through a prism is called a **spectrum** (spek′trəm). Of course you have seen a spectrum before. When you see a rainbow, you see a spectrum. A rainbow appears when light passes through drops of water. Drops of water can act like prisms when sunlight is reflected from inside the drops.

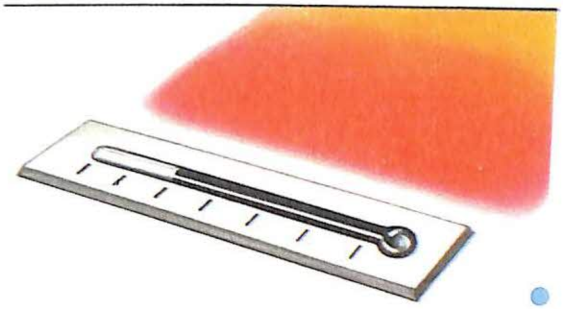
What does this spectrum mean? It means that the white light of the Sun is not a simple thing. *White light is made of many different colors of light.* The prism sorts white light into these different colors.

The prism sorts out something else, as well. It sorts out some light we cannot see. How this light that we cannot see was discovered is an interesting story.

Light We Cannot See

In the year 1800 a scientist named Sir William Herschel looked at the colored bands in a spectrum of sunlight, and wondered. He wondered which of these bands of color had the most heat. Herschel designed an experiment. He placed the bulb of a thermometer in each band of color for a while, and observed its temperature. The red band had the highest temperature, he found. ■





He found something else, however, something he had not expected at all. He held the thermometer bulb just outside the red end of the spectrum. There was no light to be seen there. Yet the temperature rose even higher! ●

William Herschel reasoned that there must be a kind of light there that the eye could not see. He reasoned that this invisible light raised the temperature of the thermometer. More experiments showed that he was right.

We call this kind of invisible light **infrared light.** *Infra* means "below." This light is below the red band of the spectrum. Our eyes cannot see this light, but a special type of camera film can. So photographs may be taken in the dark by infrared light. Because infrared light is invisible, you may not know that you have been photographed.

At the other end of the spectrum is the violet band. Beyond the violet band is another kind of invisible light. It is called **ultraviolet light.** *Ultra* means "beyond." Probably you know of ultraviolet lamps, which can produce a suntan. Usually such lamps give off some visible light. We know that some insects can see ultraviolet light.

The prism sorts out the colors that make up white light. It sorts out some invisible light as well. Certainly light is no simple thing!

White light is made up of colored light. Some light is invisible. Light can be reflected. Light travels in straight lines. These are facts. How do scientists explain these facts? Do scientists have a theory to explain the way light behaves? They do have a theory. Indeed, they have *two* theories. Sometimes one theory works, sometimes the other. We shall look at these theories and see what behavior of light each seems to explain.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. Light is reflected in
   a. curved lines　　b. straight lines
2. White light can be broken up into light of
   a. one color　　b. different colors
3. A spectrum results when light is broken up by a
   a. prism　　b. mirror
4. Our eyes cannot see
   a. infrared light　　b. red light
5. Our eyes can see
   a. violet light　　b. ultraviolet light

B. Write a paragraph or two on this topic: "Light That Is Invisible."

USING WHAT YOU KNOW

1. It was a dark night. The thieves coming out of the building thought they were safe. They saw no lights and heard no sounds. However, a special camera had taken pictures of the thieves in the dark. Later they were caught.

How was this possible?

2. Two boys watching fish in an aquarium suddenly saw a rainbow of colors, a spectrum, as the Sun shone through the tank.

How was this possible?

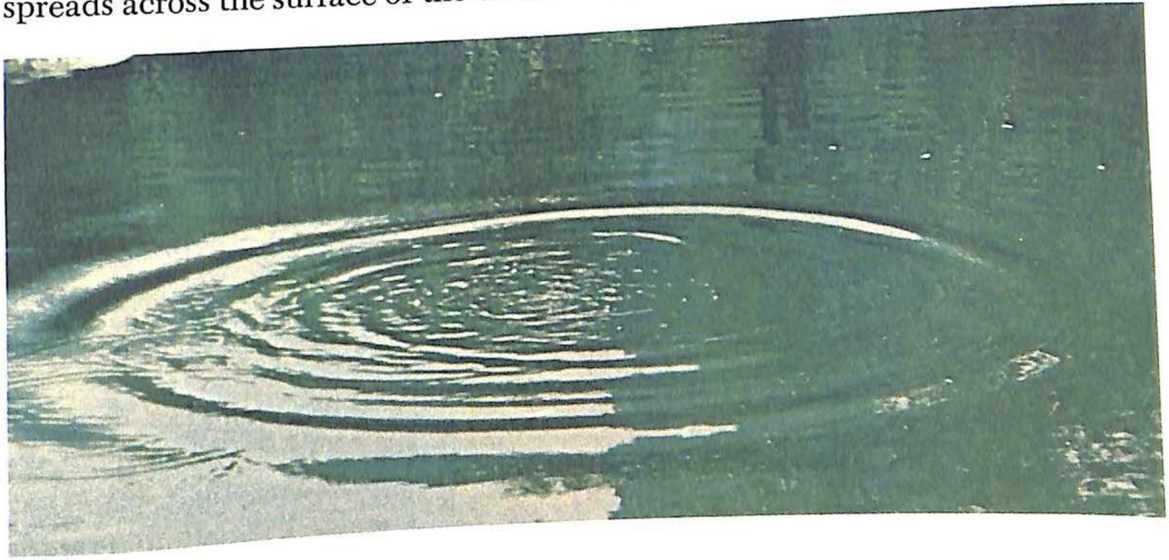
ON YOUR OWN

Set up an aquarium tank in sunlight and fill it with clear water. In what position must the aquarium be to make a spectrum?

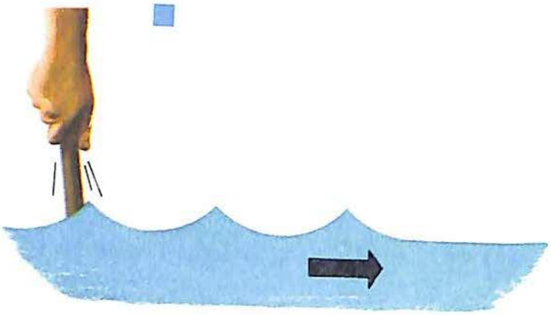
Make a diagram that shows the path of sunlight through the tank to the spectrum.

3. Light as Waves

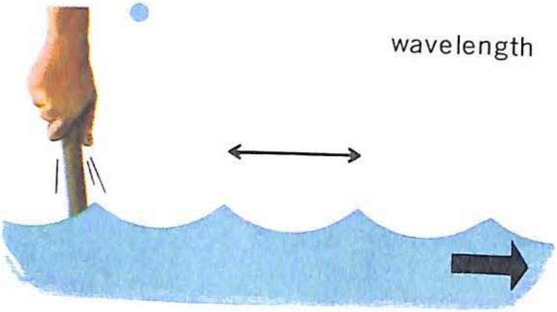
Drop a pebble into still water. Watch the wave it makes. The wave spreads across the surface of the water in all directions at once, in a growing circle. ■ The wave travels at a certain speed, until it fades away. Somehow, energy is being carried across the surface of the water. ■



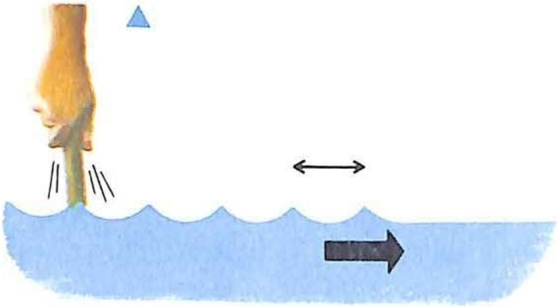
Take a stick and slowly dip its end in and out of the water. It makes a parade of waves. One wave follows another across the water, all at the same speed. If the stick dips in and out with a steady rhythm, the waves follow each other at the same distance. ■



This distance from the top part or **crest** of one wave to the crest of the next, is called the **wavelength.** If the stick dips in and out with a steady rhythm, the waves all have the same wavelength. ●



Suppose that the stick is dipped in and out quickly. Do the waves move across the water more quickly? No—they move at the same speed as before. However, there is a difference.



The waves are closer together. ▲ In other words, the wavelength is shorter. Waves can have different wavelengths. You can see this for yourself in a bathtub.

The Wave Theory of Light

Now one theory about light is that light is made up of waves. According to this theory, when you turn on a lamp, waves of light go out in all directions, somewhat like the waves on a pond. We're not saying that light waves look just like water waves. However, light waves do have crests of a kind. In fact, scientists have measured the wavelength of light waves, the distance from one crest to the next.

The wavelength of a light wave is very short indeed. The light we see as red, for instance, has about 30,000 waves in an inch! So one wavelength of red light is only $\frac{1}{30,000}$ of an inch long.

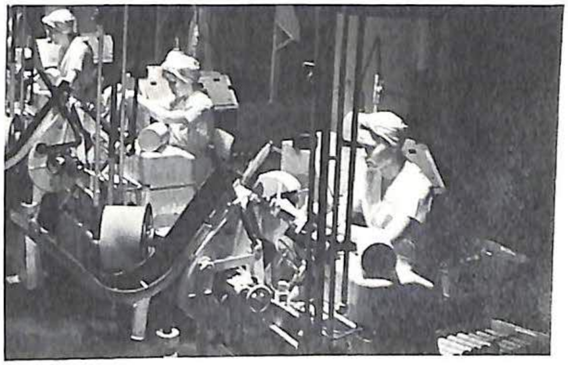
Red light is at one end of the spectrum, you remember. What about the color we see at the other end of the spectrum—violet? Violet light has a *different* wavelength from red light. It has about 65,000 waves in an inch. So the wavelength of violet light is $\frac{1}{65,000}$ of an inch.

What of the other colors we see in the spectrum, the colors between violet and red? Scientists have measured their wavelengths too. What about the invisible light beyond each end of the visible spectrum? The wavelength has been measured.

Here are about the number of waves to the inch to be found in each color of the spectrum:

Waves in an inch	*Color*	
70,000	ultraviolet (invisible)	
65,000	violet	🟪
55,000	blue	🟦
48,000	green	🟩
44,000	yellow	🟨
36,000	orange	🟧
30,000	red	🟥
25,000	infrared (invisible)	

Our eyes sense the colors in the spectrum from red to violet. Now we can say this in another way. Our eyes sense light that has between 30,000 and 65,000 waves in an inch. Human eyes usually do not sense waves longer than the red waves or shorter than the violet waves in the spectrum. However there are some insects, such as bees, that can sense ultraviolet waves. And this photograph was taken in the dark, with infrared light. ◆



◆

Did you know that some people cannot see all the colors in the spectrum? Some people are *color-blind*, that is, their eyes do not sense certain colors. For instance, a person with one kind of color blindness cannot sense any difference between red and green. Such a person is usually able to see other colors, however.

You might think that since scientists have managed to measure the wavelength of light, the wave theory of light must be true. Light must be made of waves, surely. In fact, there is a good deal more evidence in favor of the wave theory.

However, there is evidence that seems to point to a different theory of what light is!

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

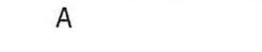
1. The top of a wave is called the
   a. crest
   b. valley
2. The wavelength is shortest for
   a. infrared light
   b. ultraviolet light
3. One kind of light which is invisible is
   a. red light
   b. infrared light
4. One theory of light is that light is made up of
   a. waves
   b. molecules
5. A theory
   a. is always true
   b. can be changed if the evidence changes

B. Write a paragraph or two on this topic: "The Wave Theory of Light."

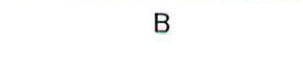
USING WHAT YOU KNOW

1. List the following colors in an order which you can explain by their wavelengths: green, yellow, blue, red. What is your explanation?

2. Which of these wavelengths is shorter?



A



B

4. Light as Particles

As you know, photographers often use a light meter when taking pictures to measure the strength of the light. Perhaps you have used one yourself if you have a hobby of taking pictures. Here is a light meter. ■ How does it work?

■

Light produces an electric current in the meter. Strong light produces a strong current. Weak light produces a weak current. By measuring the strength of the electric current, the strength of the light is measured.

How does light produce an electric current in the meter? On the meter there is a plate of a kind of metal called *selenium* (si·lē′nē·əm). When light strikes selenium, selenium gives off tiny bits of matter called **electrons.** Electrons are what make up an electric current. Strong light makes many electrons jump off selenium. A strong electric current is produced. Weak light means that few electrons leave the selenium. A weak electric current is produced. And here something unexpected happens.

Another Theory of Light

When light strikes selenium, electrons jump off. The weaker the light is, the fewer the electrons that leave. Now, it is possible to make the light so weak that just *one* electron jumps off.

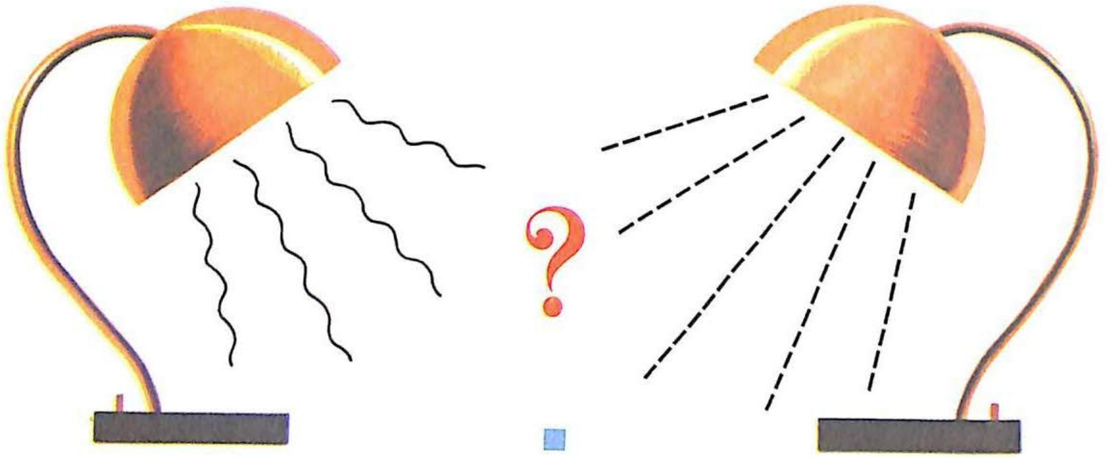
This shouldn't happen, if light is a wave.

A wave of light cannot make just one electron jump off. A wave of light hasn't energy enough. Only a *particle,* a speck, can do that job. A particle has concentrated energy, like a tiny bullet.

In this case, then, light behaves as if it were made up of particles, not waves. To explain why an electron jumps off selenium, the particle theory of light is needed. The wave theory just doesn't work. The wave theory of light doesn't explain the way selenium acts when light shines on it.

The particle theory is that light is made up of very tiny specks or particles. According to this theory, when you turn on a lamp, tiny particles of light fly out from the lamp in all directions, in great numbers.

A particle of light is called a **photon** (fō′ton). Think of a photon as a tiny packet of energy, a speck of light en-



ergy. When you point a flashlight at someone and turn it on, you squirt a stream of photons at that person. Streams of photons are rushing to the Earth from the Sun. And it is photons that make electrons leap from the surface of selenium, according to the particle theory of light.

There is more evidence in favor of the particle theory, which we can't go into here. What all the evidence comes to is this, however. **At times light behaves as if it were made up of particles. At times light behaves as if it were made up of waves.** So there are two theories about light, the particle theory and the wave theory. ■

Which theory is better? Scientists must get more evidence before they can tell. Part of the trouble is this: The particles we can see around us do not behave like waves. The waves we see around us do not behave like particles. So we find it very hard to imagine that light can be *both* particle and wave. Yet perhaps it may be so, when things are extremely small. It seems that the world of extremely small things, such as photons, is not like the world we know. At any rate, in science we can wait for more evidence before deciding. The collecting of evidence is going on now. It will continue to go on.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. When light strikes the metal selenium, the selenium gives off

a. electrons b. protons

2. When light makes electrons jump off selenium, light acts like a

a. wave b. particle

3. According to the particle theory of light, when we turn on a lamp tiny particles fly out. These particles are called

a. photons b. protons

4. To explain why light behaves as it does, scientists use

a. one theory b. two theories

B. Write a paragraph or two on this topic: "The Particle Theory of Light."

USING WHAT YOU KNOW

1. Here are two pieces of evidence:

a. Light can be broken up by a prism into a spectrum.

b. Light can knock an electron out of a metal like selenium.

Which of these is best explained by the wave theory of light? Which is best explained by the particle theory of light?

2. Isaac Newton investigated breaking up light with a prism. What other work is Newton known for?

ON YOUR OWN

Many scientists worked to find out the nature of light. One of them was Christian Huygens (hī′gənz). What work did he do? Which theory of light does his work support?

5. What Light from the Stars Shows

To find out what a cake is made of, you take a bit of it and test it—usually by putting it in your mouth. To find out what the Earth is made of, we take bits of its rocks and minerals and test them in various ways.

Unfortunately, we can't get bits of the stars to test. Of course our Sun is a star, and much nearer to us than any of the other stars. Even so, it is too far away. We can't get bits of the Sun to test, either. Yet we have managed to find out much about what the Sun and other stars are made of. How? By studying the *light* that comes to Earth from the Sun and from the stars.

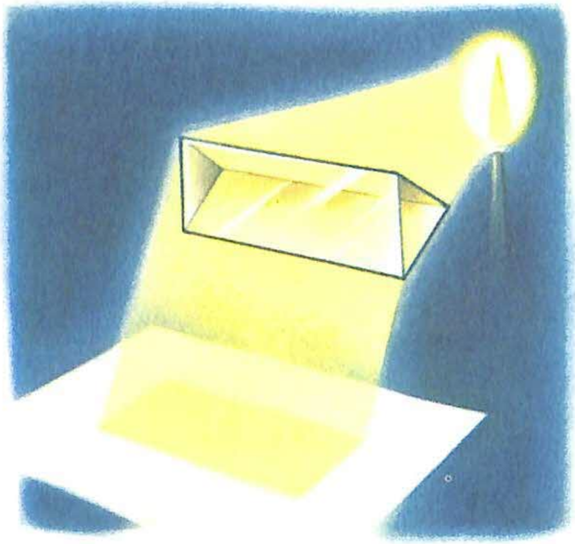
Think of what happens when light from the Sun is sent through a prism. A spectrum is formed, a pattern of colors. The spectrum shows that white light from the Sun is actually made up of light of many different colors. You studied the Sun's spectrum.

Scientists have an instrument that allows them to study a spectrum very closely and exactly. This instrument for studying a spectrum is called a *spectroscope* (spek′trə·skōp). Astronomers have found out much of what they know about the stars with the spectroscope. You can get an idea of how this is done by trying the investigation on the opposite page.

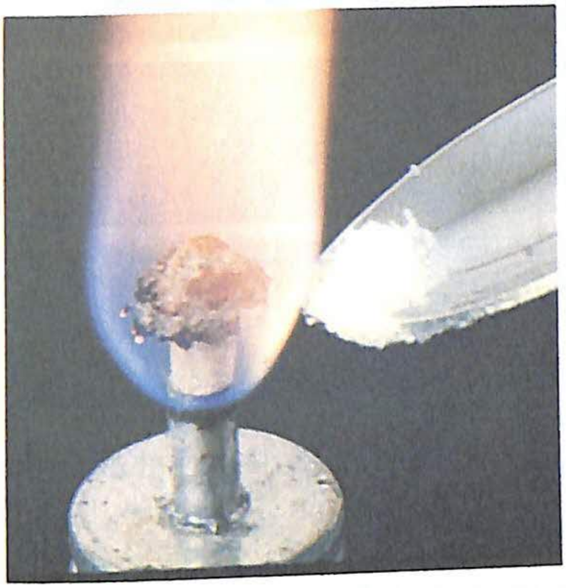
Fingerprints of the Elements

When the sodium in sodium chloride is heated in the blue flame of a burner, it produces a yellow flame. This yellow flame is one way of recognizing the element sodium.

What happens if this yellow light is sent through a glass prism? The result is a spectrum of one band only, yellow light.



AN INVESTIGATION into a Flame Test

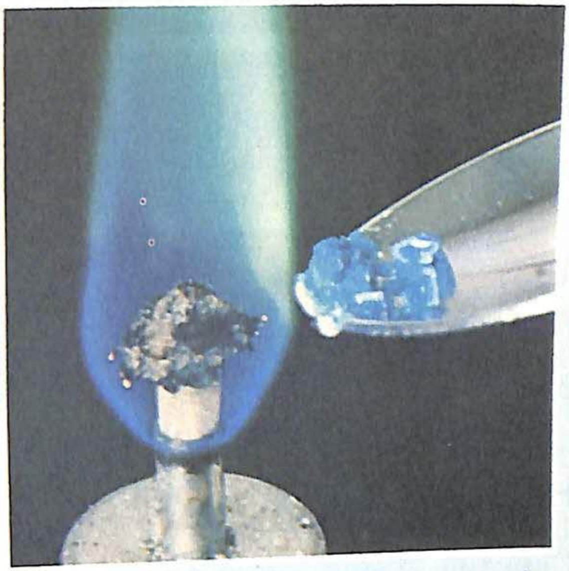

■

Needed: sodium chloride, copper sulfate, strontium chloride powders; a Bunsen burner or alcohol lamp, a stainless steel teaspoon

Sodium chloride is common table salt. The other substances can be obtained by your teacher. If the copper sulfate comes in crystals, you can easily grind one or two into powder.

Light the burner. (Be sure that your teacher is present when you work with a flame.) Its flame should be made as blue as possible, by adjusting the air opening at the bottom. Wet the tip of the teaspoon with water so that powder will stick to it. Dip the tip of the teaspoon in the sodium chloride. Then hold in the flame the sodium chloride that sticks to the tip. Here is what happened on one trial. ■

What color is the flame?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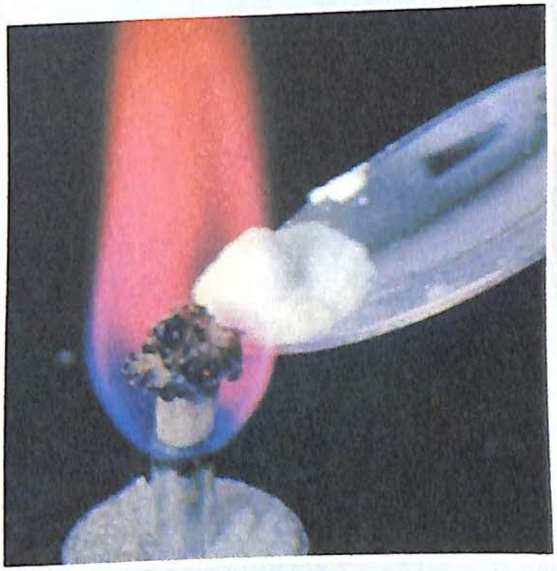
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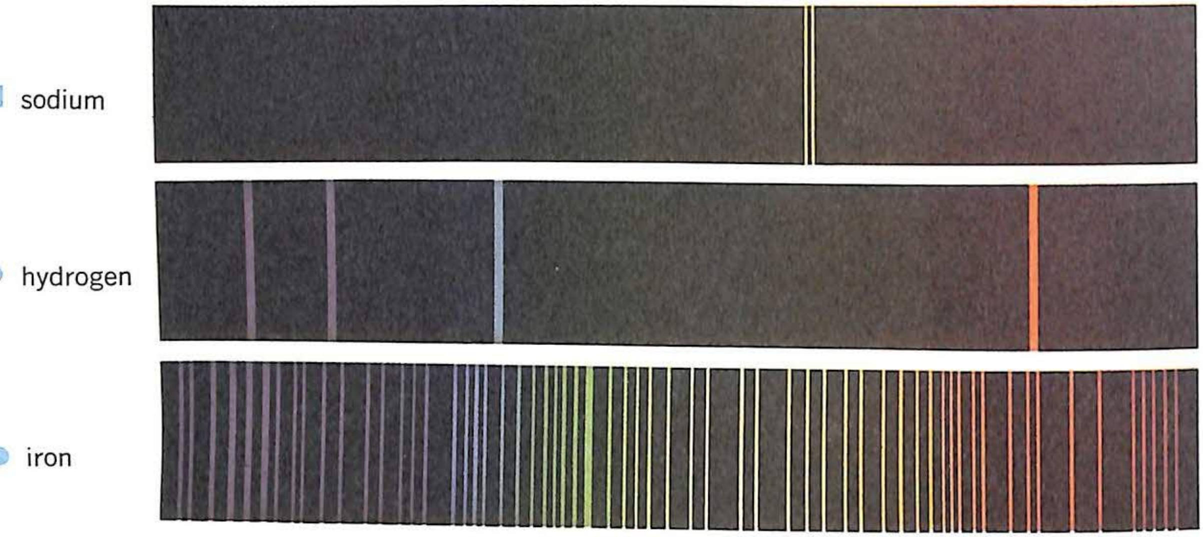
This is called a *flame test*. When a compound has sodium in it, the flame is yellow.

Try the flame test with copper sulfate. ● Do the flame test with strontium chloride. ▲ What flame colors do copper and strontium show?



Send the yellow light through a spectroscope, however, and you may see two thin yellow lines, for a spectroscope is more exact. ■ This spectrum of two yellow lines is the fingerprint of sodium, so to speak. Sodium always produces these same two lines in a spectroscope, when sodium is heated to a gas.

Most substances can be turned into gases by heating them. If the gas is heated enough, the substance gives off light. Examine that light through a spectroscope, and you will find something astonishing. *Each substance has its own spectrum.* Here are the spectrums of iron and hydrogen, for example. ● Notice that each substance has its own spectrum. The color of the lines in each spectrum, and where the lines are, is a property of that substance, and only that substance. These are the fingerprints of hydrogen and iron.

What has this to do with the stars? Well, let's take our Sun for example. The Sun is so hot that all the substances in it are hot gases, giving off light. Aim a spectroscope at the Sun. Take a photograph of its spectrum. Many different lines appear, in many different places. But among these lines the astronomer can recognize the spectrums of substances we know!

With the spectroscope, astronomers have found about sixty-two substances in the Sun. Hydrogen, aluminum, tin, lead, and iron are among them. Each substance has been identified by its fingerprint, its spectrum. This is how we know what the Sun is made of, even though we never have had a bit of the Sun to test.

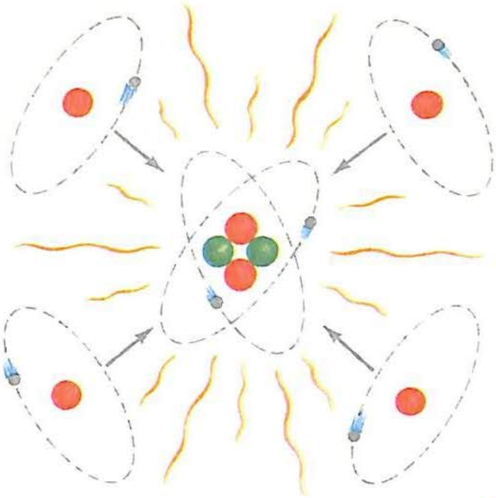
The Spectroscope Searches the Stars

The astronomer turns his spectroscope on the star he wants to study. He does this on a dark night when the sky is clear. The spectroscope is attached to a telescope. A camera attached to the spectroscope records the spectrum on film.

Carefully, the telescope is aimed at the star, and the telescope machinery keeps the spectroscope aimed. The shutter of the camera is opened. Depending on the star, the shutter may be opened to the star's light for an hour, for several hours, or even for several nights.

When the astronomer has the record of the star's light on the film, he can study the star's spectrum. By identifying sets of colored lines, he can identify the substances in that star. Many observations with spectroscopes have shown scientists that most bright stars are made mainly of hydrogen and helium. The Sun and other stars do contain many substances that are found on the Earth. However, these substances are present in very small amounts. Our Sun and many other stars are mainly hydrogen and helium gas. Scientists believe that the hydrogen is turning into helium.

Hydrogen becomes helium. This means that an atom of one kind becomes an atom of another kind. Do you recall that we came across a change like this before? Radioactive uranium atoms became lead atoms, changing from one kind of atom to another. As this happened, energy was given off.



▲

When hydrogen turns into helium, energy is given off. In fact, this is the energy that makes our Sun, and other stars, give off heat and light. The energy made as hydrogen turns into helium is the energy that keeps us alive.

How does hydrogen turn into helium and give off energy? Four atoms of hydrogen join together to form one atom of helium. ▲ We say that the atoms of hydrogen *fuse* to form helium. This **fusion** happens only at a tremendously high temperature, such as exists in the Sun. When four hydrogen atoms fuse to form a helium atom, a little of their matter disappears. This matter that disappears is turned into energy.

The building blocks of the Sun and other stars are atoms like those on Earth. However, on the Sun most of the atoms are hydrogen and helium atoms. Close to 99/100 of the Sun's mass is hydrogen and helium. Because of the high temperature of the Sun, these atoms behave differently from the way they do on Earth. Let's leave this interesting idea for later study.

This, then, is where our star, the Sun, gets its energy. This is how *we* get the light energy and heat energy that makes life on Earth possible. That hydrogen atoms can fuse to make helium atoms is pretty important to us. The energy that is given off, when this happens, keeps us alive.

You may be wondering now, how long can this go on? Won't the Sun in time run out of hydrogen to fuse into helium? It will, so far as we know. However, astronomers have calculated that it will take a long, long time, a trillion years or so.

By then our descendants may have moved to another planet.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. An instrument for studying the spectrum is the
   a. spectroscope b. microscope

2. A substance heated in a flame until it becomes a gas shows its own
   a. compounds b. spectrum

3. By using the spectroscope, scientists have discovered on the Sun many substances
   a. like those on Earth b. unlike those on Earth

4. The spectrum of the Sun shows that most of the mass of the Sun is made up of the gases
   a. hydrogen and helium b. hydrogen and oxygen

5. The Sun gets its energy from the fusion of hydrogen into
   a. helium b. oxygen

B. Write a paragraph or two on one of these topics: "The Sun, Our First Source of Energy," or "The Importance of Hydrogen."

USING WHAT YOU KNOW

1. Suppose that more than nine tenths of a body in space is made up of heavy metals such as iron, lead, copper, and other substances such as sulfur, oxygen, and nitrogen. There is about 1 percent of hydrogen on the body.

Is this body most likely to be a star, or a planet?

2. When hydrogen turns into helium, some of its matter is destroyed. What happens to this matter that disappears?

ON YOUR OWN

Make a model to show how hydrogen atoms come together to form helium atoms and energy. Ping-Pong balls make good atom models, for example. They are easily glued and painted.

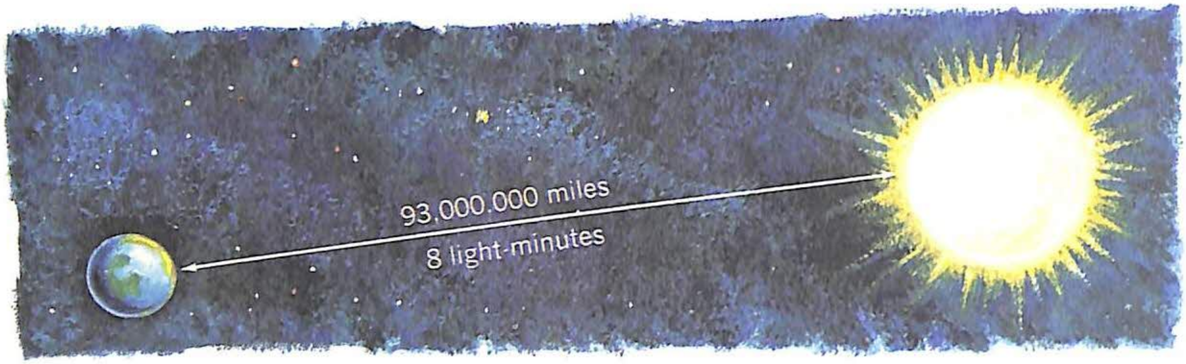
6. A Ruler to the Stars

If you wanted to measure the distance from the top of this page to the bottom, you'd probably reach for a ruler. Using a ruler, as you know, is a way of measuring distance. You must have used one often. But have you ever thought what different rulers we make use of?

We use different kinds of rulers for measuring distance. Sometimes we measure distance in units of *length*, such as inches, feet, and miles. Sometimes we measure distance in units of *time*, such as minutes, days, and years. For example, we may say that a certain town is 30 miles away. Or we may say that it is an hour away. When we say that the town is an hour away, of course we mean that a car would reach it in about an hour. When we speak of distance in this way, we are using a ruler that measures distance in units of time.

We often make use of this "time" ruler. "How far do you live from school?" asks one student. "Oh, about 5 minutes' walk," says the other. This distance from school to his home is about 5 walking-minutes, in other words. Or the distance to that certain town is about 1 car-hour—the distance a car can travel in an hour. The distance from New York to London is about 6½ jet-hours—the distance that a jet plane can travel in 6½ hours.

We often measure distance in units of time. Notice that when we do so, we are careful about two things. First, we make clear what is doing the traveling—a car, a plane, or whatever it may be. Second, the distance covered in each unit of time is always the



same. It should not be 2 miles in one minute, and 4 miles in the next minute. The distance covered in each minute must be the same.

We often use the ruler of units of length when we speak of the distance to the Sun. The distance to the Sun is 93 million miles. However, the distance to the Sun could be measured with the ruler of units of time, too. Suppose that you can walk a mile in 15 minutes. Then it would take about 23 million hours to walk the distance to the Sun! This is about 1 million days. So it would be correct to say that the distance to the Sun, from where you are on the Earth, is about 1 million walking-days.

A walking-day is not a very good unit to use, is it? Distances in space are very great. The *nearest* star, for instance, not counting the Sun, is about 25,000,000,000,000 miles away. (This is 25 trillion miles.) Astronomers would want a ruler for measuring distances in space that would give smaller numbers, if possible. In fact, astronomers have made such a ruler. Before we look at this ruler, however, let's get an idea of how distance can be measured in our solar system. Try the investigation on the opposite page.

A Ruler Made of Light

For many centuries men believed that light took no time at all to go from one place to another. They believed that the speed of light could not be measured.

However, scientists later discovered that light has a definite speed. They have measured the speed at which light travels, in many experiments. It is no wonder that men thought that light took no time at all to get from one place to another. **The speed of light is 186,000 miles per second.**

In one second light can travel a distance of more than seven times around the Earth. In the time it takes you to blink an eye—about a tenth of a second—light travels about 18,000 miles.

The nearest star to the Earth, our Sun, is 93 million miles away. It takes about 8 minutes for light to travel that distance, traveling at 186,000 miles per second. ■ So we can say

AN INVESTIGATION into Measuring Distance Without a Ruler

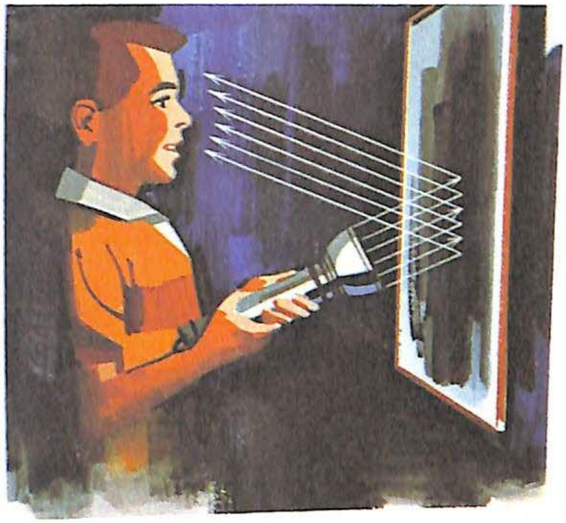
Needed: a mirror, a flashlight, a dark room, a radio

Take a flashlight and try to find a mirror in a dark room. How do you find it? You know light will be reflected from the mirror. Turn your flashlight until you see the flash of light in the mirror. The light is bouncing back at you. ■ This is one idea behind measuring distances between planets. Light energy is not used, however. A form of energy with the speed of light, a radio wave, is used.

Scientists have taken great pains to measure the speed of radio waves. Radio waves travel at the same speed as light, 186,000 miles a second. Radio waves can be sent out into space and bounced off objects in space. Radio waves can be bounced off the Moon, and caught when they come back to the Earth. This is what radar equipment does. ●

We know that a radio wave can go to the Moon, bounce, and return to the Earth in 2.6 seconds. The trip to the Moon takes 1.3 seconds, the trip back to Earth takes another 1.3 seconds.

Can you calculate the distance to the Moon?



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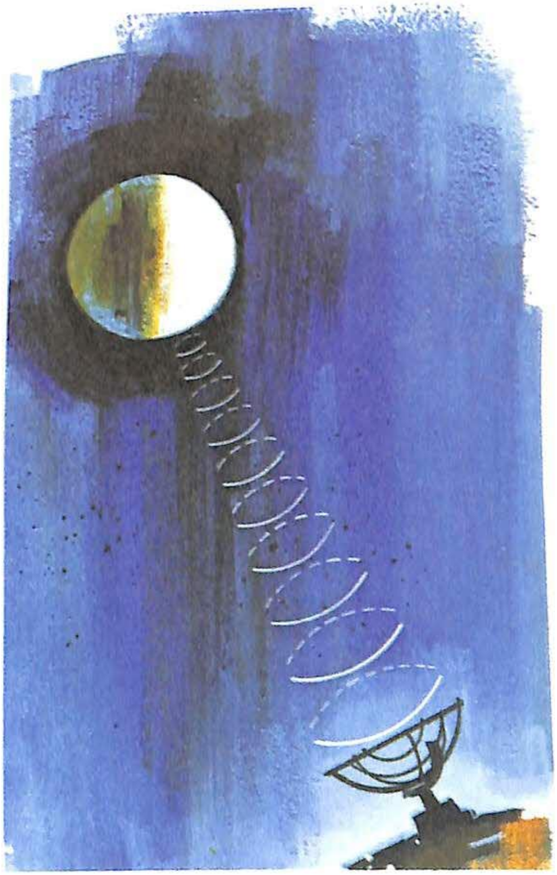


●

that the Sun is 8 light-minutes away from the Earth.

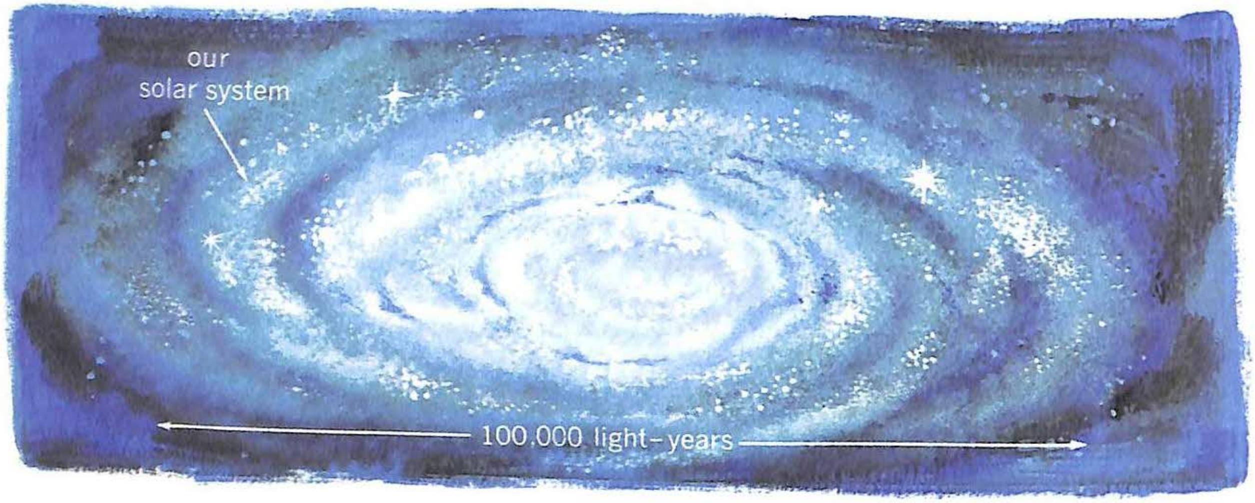
The next nearest star, some 25 trillion miles away, is Alpha Centauri (al′fə sen·tôr′ē). Alpha Centauri is about 270,000 times farther away from us than the Sun. The distance from the Earth to Alpha Centauri is about 2,200,000 light-minutes. This is the distance that light travels in 2,200,000 minutes, at a speed of 186,000 miles per second.

Now we are getting into larger numbers again! We can get around this, though, by using a larger unit of time. What is a larger unit of time than the minute? Astronomers have decided to use a *year* as the unit of time. As a ruler for measuring distances in space, astronomers use the **light-year.** A light-year is the distance light travels in one year.

What is the distance to Alpha Centauri in light-years? Alpha Centauri is $4\frac{1}{3}$ light-years from the Earth. That is, it takes light $4\frac{1}{3}$ years to travel the distance from Alpha Centauri to Earth, at the speed of 186,000 miles every second of that time.

Alpha Centauri is $4\frac{1}{3}$ light-years distant from our Earth. This is an easier number to work with than 25 trillion miles, certainly. Perhaps it is easier to imagine, too. If you could travel in a rocket ship at the speed of light, it would take you about 4 years and 4 months to reach Alpha Centauri. Traveling at the speed of light, it would take you 100,000 years to cross our Milky Way Galaxy from edge to edge, as in the figure. In other words, the distance across the Milky Way Galaxy is 100,000 light-years. Our solar system, the Sun and its planets, are about 34,000 light-years distant from the center of the galaxy, and about 16,000 light-years from the outer fringe.

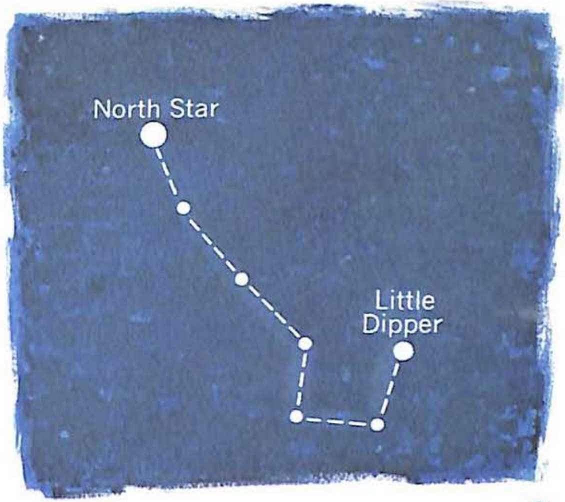
How far away are the farthest stars we can detect? With the help of the



Big Eye on Mount Palomar we have recorded, on film, light from a group of stars 16 billion light-years away!

Look up at the stars tonight. Look at the North Star, in the Little Dipper.● Its light takes about 400 years to reach you. Light from most of the other stars you see takes many more years to reach you.

You see the universe only as it was, never as it is.



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BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A unit of length is the
a. minute b. inch

2. A unit of time is the
a. year b. mile

3. Light travels from the Sun, 93 million miles away, to the Earth in about
a. 8 minutes b. 16 minutes

4. The light-year is a unit for measuring
a. distance b. time

B. Write a paragraph or two on this topic: "A Ruler for the Universe."

USING WHAT YOU KNOW

1. Suppose that a spaceship could travel at the speed of light. (It's impossible, we know, but suppose it could.) How long would the spaceship take to reach
a. Alpha Centauri?
b. a star 400 light-years away?

2. The Sun and the Earth are made up of similar building blocks.

There is at least one difference, however. That difference is in the amounts of hydrogen and helium on the Earth and on the Sun.

  a. Why is the difference important?
  b. What happens to hydrogen on the Sun?

ON YOUR OWN Find out the distances, in light-years, to these stars:

1. Sirius (the Dog Star)
2. a star in the constellation called Orion (the Hunter)
3. a star in the Big Dipper
4. a star in the Little Dipper

7. The Main Concept: Building Blocks of the Stars

We began by studying the Earth. Now we have reached out into space to study the building blocks of the stars. We can't scoop out bits of stars to examine. So we study the light that the stars give off. ■

White light can be broken up into a spectrum, for it is made up of light of different colors—red, orange, yellow, green, blue, violet. When a substance is heated to a gas, that gas gives off light. That light has its own spectrum. Thus each substance can be identified by its spectrum. The spectrum of a substance may identify the substance as a fingerprint identifies a person.

A telescope collects light from a star. A spectroscope attached to the telescope shows the spectrum of the star. By studying that spectrum, the substances of which the star is made can be identified. Thus, by studying the light from a star, we discover the building blocks of the star.

The building blocks of the stars are atoms much the same as those we know on Earth. The stars, however, are made up almost entirely of atoms

of hydrogen and helium. More than 99/100 of all the Sun's mass is made up of hydrogen and helium. Only a very small part of the Earth is hydrogen and helium gas.

In the Sun, hydrogen atoms fuse to produce helium atoms. As they do so, part of the mass of the hydrogen atoms is changed into energy. On Earth, we depend on the Sun's energy. Green plants use the Sun's light energy to make food. Heat energy gives the Earth the temperature needed by its living things.

The light of a star shows where the star is. We use the time light takes to travel the distance from star to Earth, to tell how far away a star is. We call this unit of distance a light-year.

For ages people have thought of the stars as unchanging. Now we know that the stars, as well as our star, the Sun, are always changing. Now we know that the matter of the stars is being changed into energy. We know that the stars are moving at tremendous speeds.

We live in a changing world.

Fixing the Main Concepts

TESTING YOURSELF

A. Test your understanding of important concepts in this unit by doing these problems.

1. We are all unable to see some wavelengths of light. In other words, we cannot see some parts of the spectrum of white light.

Which parts of the spectrum can't we see? Which parts can we see?

2. An engineer built a special kind of lock for a door. When he wanted to lock the door he flashed light on a plate of selenium metal. In this way a current of electricity was started. The electricity was used to lock the door.

A theory of light which helps explain this lock is the

a. wave theory
b. particle theory

3. Examine your text carefully on this point. Which wavelength should be used to produce the greater amount of heat, a long wavelength or a short wavelength?

4. How does the Sun produce such a great amount of energy?

B. Test your understanding of concepts in this unit by using each of these key words or phrases in a sentence.

reflected
focus
telescope
telescope mirror
prism
wavelength
fusion
selenium
photon
spectrum
ultraviolet
infrared
particle theory
wave theory
hydrogen becomes helium
light-year
electron
spectroscope

C. Test your knowledge with this quick check.

1. Which one of these colors has the longest wavelength?

a. violet
c. blue
b. orange
d. red

2. In the Hale telescope, light is collected by a

a. camera
c. mirror
b. cage
d. telescope

3. On the Sun, energy is produced when

a. oxygen is burned
b. hydrogen is burned
c. hydrogen is turned into helium
d. oxygen is turned into helium

4. A rainbow is an example of

a. a light-year
c. fusion
b. a flame test
d. a spectrum

5. To stay pointed at one star, a telescope must

a. focus
c. collect light
b. move
d. not move

6. Light can make an electron jump off selenium. This can be explained by

a. the wave theory
c. both theories
b. the particle theory
d. neither theory

7. A light-year is used to measure

a. weight
c. distance
b. force
d. time

8. The important thing to observe when you are doing a flame test is

a. smell
c. boiling
b. temperature
d. color

ON YOUR OWN Investigations and Projects

1. In the Library

Sir William Herschel did more than investigate the spectrum. Find out more about Herschel, a truly great scientist. You may be surprised to find who was his great friend among scientists.

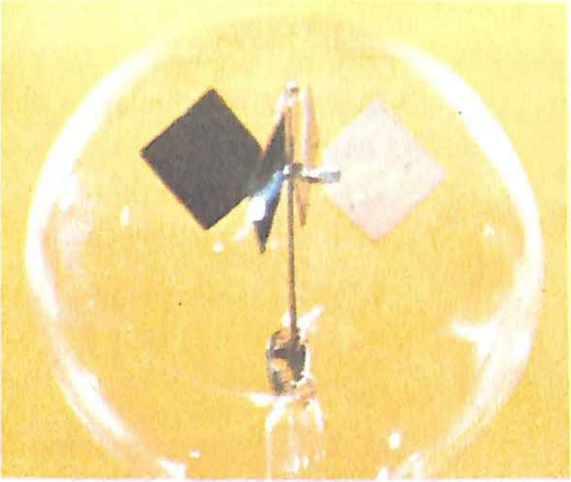
2. At Home

New experiments with light are going on now. One that is often written about in newspapers is the *laser*. Take for a project "A Report on the Laser."

Share the report with your class.

3. Investigations

a. Perhaps you like to take photographs, or perhaps your father does. You or he may have a light meter. What makes the meter reading change? How does the meter change light into the movement of a pointer?



b. In a radiometer, one side of the square pieces of metal (called vanes) is shiny, the other side, black. The square pieces of thin metal turn in light. The brighter the light, the faster they turn. Is either theory of light needed to explain the turning of the vanes?

These are difficult questions. You may want to leave them until you have studied light more thoroughly.

FOR YOUR READING

1. *The Stars for Sam,* by W. Maxwell Reed, published by Harcourt, Brace & World, New York, 1960. Here is a useful book which will take you further toward an understanding of the stars. There are chapters on light from the stars and the uses of the spectroscope.

2. *Space in Your Future,* by Leo Schneider, published by Harcourt, Brace & World, New York, 1961. This is a good account of how the astronomer uses his tools.

3. *Experiments in Sky Watching,* by Franklyn M. Branley, published by Thomas Y. Crowell, New York, 1959. For the interested student there are some very good ideas for projects in astronomy.

GOING FURTHER

You've seen light bulbs of different colors. The *glass* of which the bulb is made is colored—red, green, yellow, blue, whatever it may be. However, the light produced inside the bulb is white light. How is it that you see only one color of light through the bulb?

What does blue glass or red glass, or some other color of glass, do to white light? Design an investigation to answer this question. Colored glass may be difficult to get. Colored cellophane or plastic will do just as well.

Here is a suggestion to start you off. You can break up white light into its spectrum. (Use a prism and sunlight as shown on page 278.) This is a way of getting the different colors of light. What does colored plastic or glass do to the spectrum?

CONCEPTUAL SCHEME

Living things are in constant change.

(*Text pages 304–341*)

Unit Eight

STORIES IN THE EARTH

UNIT CONCEPT

Living things have changed over the ages.

Children follow, in the story of the Earth, the development of life from simple to complex organisms. They come to an understanding of how scientists are able to piece together, from fossils and other evidence, the kinds of life and environment that existed in the past. They appreciate more fully the continuity of change in living things on Earth from its earliest past up to its present.

A Preview of the Concepts

A VIEW OF THE UNIT

This unit offers opportunity to review and relate many unit concepts and subconcepts that have been presented earlier in this year's course in science. For example, without a knowledge of sedimentation and the processes of shifting in the Earth's crust, scientists would be unable to determine the sequence in which different forms of plant and animal life appeared on Earth. Similarly, the age of the fossils could not be determined without knowledge of the rate of sedimentation and of the decay of radioactive uranium into the stable element lead. Knowledge of the structure of organisms enables scientists to fit fossilized remains together and describe with accuracy the kinds of life that existed in the environments of the past. Relationships between living things and environmental conditions also help scientists understand how adaptations made certain living things dominant in their geological period and how lack of adaptation led to their becoming extinct. Finally, understanding of how changes take place in chromosome content helps them explain the appearance of new life forms and structural adaptations to the environment. All of these interrelationships bear on the conceptual understandings that living things change and that the Earth is a part of a universe that is in continual change.

The children start by reexamining the importance of bone structure in relation to the functions an animal can perform. How bones fit together and the kinds of motion the joints permit are a type of clue that fossil hunters follow up. The structural changes from the foxlike Dawn horse to the modern horse are traced through the sedimentary layers of 60 million years.

From this fairly recent age in the Earth's history, the children go back to life's beginnings in the ancient waters. They apply the concepts they have learned to understanding the structural changes from invertebrates to vertebrates in the waters, to the appearance of amphibians, reptiles, birds, and eventually to the mammals of today. Throughout, the importance of adaptation to the environment is stressed, and children are given the opportunity to hypothesize on the way adaptations arise and to fashion theories concerning the relationships of living things. They keep before them the concept of the environment as a totality of the matter, the living things, and the physical conditions in it. The only constant is change itself. Children recognizing the universality of change, may appreciate more fully how knowledge of science aids them in adapting to their environments.

SUPPLEMENTARY AIDS

Films

All films and filmstrips are in full color. Names and addresses of distributors and suppliers are on page F–25.

The Dinosaur Age (14½ min.), F.A. Presents the Age of Dinosaurs through the work of museum paleontologists as they discover the fossil remains of a giant reptile and reconstruct its skeleton. You will see how man has learned about life on Earth. (Intermediate)

Fossils Are Interesting (11 min.), F.A. Introduces the concept of the Earth's changing surface and changing life. Shows how fossils are formed, how they may be found, and how they help to tell us the story of the Earth's past. (Intermediate)

Prehistoric Animals of Tar Pits (14 min.), F.A. Introduces the tar-pit animals, describes how they were found, illustrates how scientists reconstruct their skeletons, and what we learn from them. (Intermediate)

Rocks and Minerals (11 min.), F.A. Illustrates formation of three basically different kinds of rocks: igneous, sedimentary, and metamorphic; suggests ways of classifying. (Intermediate)

Rocks That Reveal the Past (12 min.), F.A. The sedimentary rocks in which fossils are found help scientists to learn the sequence of the appearance of living things on Earth. (Intermediate)

Rocks in Our Neighborhood (13 min.), McGraw-Hill. Tells the story of rocks, formation, general characteristics, and uses. Animation sequences show the formation of three basic types of rocks: igneous, sedimentary, and metamorphic. (Intermediate)

Filmstrips

The following filmstrips are all in the series Life Long Ago, S.V.E., 1958. It is an excellent series for visual development of the unit. All are evaluated as being intermediate in level of comprehension.

Hunting Fossils (44 frames). Shows how fossils are formed, how to identify them, where they can be found, how they are removed, preserved, recorded, and assembled.

Mammals Inherit the World (44 frames). Shows the rise of mammals from Age of Reptiles; development of different kinds of mammals; similarity of present mammals to those of earlier ages. Photographs from museums.

How We Know About Life Long Ago (41 frames). The magic world of fossils; how they help reconstruct the past. Shows how plants and animals are constructed; importance of fossils.

Up Through the Coal Age (44 frames). Shows earliest forms of life as recorded in fossils; development of animal life, trilobites, invertebrates, reptiles—emergence of land animals and plants. Shows continual change taking place.

When Reptiles Ruled the World (40 frames). Shows earlier reptiles as reconstructed from fossils—plant-eating and flesh-eating dinosaurs, sea reptiles, air reptiles.

Stories That Fossils Tell (40 frames). Traces development of animals and plants as known today—horse, camel, elephant; similarity of today's animals.

Science Reading Table

Starred titles are especially recommended for content and reading level. Addresses of publishers are on page F–24.

Ancient Elephants by William E. Scheele, World, 1958. A surprising amount of information about extinct mastodons and mammoths has been learned from fossils and cave paintings. The long development of species of animals and probable reasons for extinction of some of them are related in this account of the ancestry and development of the three kinds of elephants living today. (Average)

**The Earliest Americans* by William E. Scheele, World, 1963. Describes people who inhabited North America thousands of years before the Indians. Reconstruction of their appearance and activities has been accomplished largely by archeological finds made since 1926. Methods and techniques of archeological exploration are interwoven with the account of these findings. (Average)

From Bodies to Bones: A Story of Paleontology by William Fox and Samuel Wells, Henry Z. Walck, 1959. The first section describes in detail how the paleontologist works, with numerous examples of similarities and differences found among ancient and contemporary animals. The second section consists of three paleontological case histories—the Shasta Bison, Archaeopteryx, and the Frilled Dinosaur. (Advanced)

**In the Days of Dinosaurs* by Roy Chapman Andrews, Random House, 1959. The discovery of fossil remains of dinosaurs is highlighted by the author's account of his exploration in the Gobi Desert where he found not only skeletal remains but also dinosaur eggs. Appearance and probable activities of dinosaurs are vividly described (Easy)

**Dinosaur Hunt* by George O. Whitaker and Joan Meyers, Harcourt, Brace & World, 1965. An absorbing account of Mr. Whitaker's discovery of the first complete skeletons of *Coelophysis*, a small dinosaur, their removal, and shipment for display at the American Museum of Natural History. (Intermediate)

°*The Minerals Story* by Helen Heffernan and George Shaftel, L. W. Singer, 1963. A fictional story introduces people's need for raw materials and the activities and research needed to obtain them. Coal mining and its relationship to the production of electric power, the conservation of minerals by development of synthetic minerals and prospecting, and under-water mining, including skin-diving for gold, are included in a comprehensive treatment. (Average)

On the Face of the Earth by Marion Gill MacNeil, Henry Z. Walck, 1959. Describes the lengthy evolution of the Earth and its creatures from a gaseous solar origin to man's use of his intellect in the nuclear age. Contains much information in a brief account that deals with the concept of continuity. (Average)

°*The Secret Story of Pueblo Bonito* by Mary Elting and Michael Folsom, Harvey House, 1963. A thought-provoking account of archeological findings at an old Indian town in New Mexico. The reader is challenged to consider the lives of the inhabitants as derived from artifacts and, particularly, to deduce why the village was abandoned after being occupied for centuries. An excellent story for teachers to read to children. (Average)

The Story of Dinosaurs by Stanley and Barbara Brown, Harvey House, 1958. Describes what the Earth was like in the Age of Reptiles and the place of the Mesozoic Era in the Earth's history. Principally, a comprehensive portrayal of the dinosaurs at the time of their greatest development, enhanced by many illustrations. (Average)

What Is a Dinosaur? by Daniel Q. Posin, Benefic Press, 1961. The long extent of the time the dinosaurs lived gives them a prominent place in a chart of the geological ages found in this book. The book describes outstanding characteristics, fossil discoveries, and earth changes which brought about the extinction of the animals. (Easy)

▶ Introducing the Concept

What is the oldest book you know or have seen? You are now going to read a story written in stone; it is about a zoo without human spectators. Can you guess what this book is, and what story it tells? If you need another clue, the story is written in millions—not in millions of words but in millions of years. The leaves of this book are made of layers of rock. Can you guess what some of the illustrations are? (Fossils.)

If a fossil bone could speak, can you imagine the story it might tell? One such story is told in the four page introduction to the unit (text pages 304–307). Why is bone structure so important to scientists who study life of the past from fossils? What do you think they need to know to reconstruct, from a pile of bones, fossil animals never seen by man?

(*Text pages 308–311*)

SUBCONCEPT

The adaptations of an animal to its environment can be understood by relating bone structure to the functions served.

Processes emphasized

Investigation (reconstruction of skeleton)
Observation
Hypothesizing
Theorizing
Model making
Consulting authorities

Equipment and Materials

... illustrations of dinosaurs and fossil bones
... sedimentary rock sample
... fossils
... shell or bone
... plaster of Paris or clay

Section 1: BONES AND THEIR MEANING

By noting how one bone fits into another, children recognize how knowledge of bone structure enables scientists to piece together, from fossil evidence, the kind of animal and plant life that existed in the Earth's past ages.

Introducing the Concept

Initiate a bulletin board or science corner entitled "Zoo Without Spectators." To guide children's contributions, pin up a picture or two, say, of dinosaurs. If possible, bring in a fossil-bearing rock or, if none are available, a sedimentary rock. (*Note*. Builder's supply companies often carry samples of sedimentary rock.) If you have access to a collection of fossils, attach a few with colored yarn to a map showing points of origin. Children may now be encouraged to make a fossil *print* or *imprint* of a shell in Plasticine, plaster of Paris, or clay, or to imbed a chicken bone in a coffee can of roofing tar. Suggest hunting for news clippings or magazine articles on fossils or bringing in attractively illustrated science juveniles dealing with past life on Earth. Do not display more than a few samples at a time. The purpose of the display is to whet the children's interest and serve as a *starter* for their involvement in the display, which should be enlarged upon throughout the unit.

How can we feel sure that dinosaurs (or other animals illustrated for display) ever lived on Earth? Has anyone ever seen a live dinosaur?

How do you learn about an unknown animal just from a few fossil bones?

Children explore evidences of life in the past. They draw inferences about a fossil animal by examining the structure and functions of bones from a living animal.

Equipment and Materials

... animal or bird leg bones
... X-ray photographs of bones

Developing the Concept

What can fossil bones tell us about an ancient animal? Obtain bones showing a socket, the ball end, and a hinge end. (Cleaned bones from a disjointed leg of lamb are ideal and can be kept as part of your science supplies from year to year. Or bones from a chicken or a cow may be used.) Which end of the bone fits into the socket? What does this tell you about the movement the bones can make? What does the other end tell you about the movement that is possible? This may be a good time for the children to read the section and do the investigation on page 309.

Suppose you found a fossil bone with a knobby end; what would you suspect its function might have been? (To permit the ancient animal to turn or to walk.) Where would you place the bone in laying out the skeleton? (Where it could be attached to a socket in the body framework.) Suppose the bone was ten times as large as a chicken's leg bone; what might you suspect about the animal's size?

If your family doctor or school nurse can secure discarded X-ray photographs of bones, encourage children to relate the structure of the bones to the function. Taping lightly to a window pane will reduce handling and permit better viewing by all the children.

Structure and environment. The last paragraph of the section states that fossils formed in sediments. Stegosaurus was found in Nevada. What must Nevada have been like when Stegosaurus lived some 150 million years ago? Encourage a group of interested children to plan and construct a diorama around the great saurians (*saurus* means *lizard* or *reptile*) of the ancient past; elaboration follows in a later section. Can you see why the name *Stegosaurus* means "roofed lizard"? Twenty-five children can line up to convey a sense of his 25-foot length. Stegosaurus ate green plants. Considering its size, what must the environment have been like? Warm? Cold? Rainy? Dry? (Probably warm and moist to provide the needed food for the great size.) Can you relate the life of Stegosaurus to the capture of energy through photosynthesis? (Unit Six.)

From evidence, children infer that the environment of past animals was different from the present environment in which their fossils are found.

Extending the Concept

Source material on fossil life. Write to the Dinosaur National Monument, Vernal, Utah, for excellent and inexpensive pamphlet material on fossil life of the dinosaur era. For the address of the museums nearest your school, write to the American Association of Museums, Smithsonian Institute, Washington, D.C. 20025.

Reviewing the Concept

(Text page 311)

Before You Go On. A. 1. a 2. b 3. a

Section 2: ONLY SIXTY MILLION YEARS AGO

(Text pages 312–317)

SUBCONCEPT

Structural adaptations to environments of the past occurred slowly.

Children trace the changes of one organism, the horse, as it has adapted over a time span of sixty million years. They infer that structural changes interact with changes in the environment.

Processes emphasized

Analysis of data
Recording and reporting
  (through charts and exhibits)
Model making
Library research
Field trip

Equipment and Materials

. . . 40′–50′ of thin wire
. . . tagboard cards
. . . yardstick

Introducing the Concept

To help children develop a sense of time relationships, nothing is so useful as a semipermanent time line. It is useful to relate science and history, enabling children to see a sequence backward from the present to the immediate and distant past. With the principal's permission, enlist the aid of the school custodian to suspend a thin wire across the room at a height convenient for suspension of objects and labels and yet accessible, but above the heads of children and teacher. A diagonal gives the greatest length for time divisions. At one end of the wire hang a placard marked TODAY. Let us say that the length of the wire is about 40 feet (480″) and that it represents a time span of 600 million years. If your class is mathematically inclined, let them figure where they would hang a placard reading *The Age of Dinosaurs* (they flourished from 60 million years ago to about 200 million years ago) if you use a scale of 1 inch = 1 million years. Ten feet (120″) from TODAY is then about the right place to suspend a dinosaur cutout and the placard. Five feet (60″) from TODAY, hang a placard reading: "X lived 60 million years ago." Throughout this unit, children should be encouraged to add pictures and placards at appropriate, scaled intervals. Markers may be attached to the wire by clothespins.

Note without present comment the children's reactions to the placement of the markers. Launch a time-evaluation discussion with questions such as:

How far back can you remember? What is the oldest thing you know? (It need not be alive.) How long is a million years? How could you show this span of time?

Developing the Concept

Children infer, from recall of earlier concepts they have studied, that the age of fossils can be dated with great accuracy.

How do we know about living things of 60 million years ago? What (*Hint!*) farm animal lived 60 million years ago? After random guesses, encourage reading of the section. What animal can we now name to replace the "X" on our placard for 60 million years ago? Why did scientists who reconstructed fossils of the Dawn horse think that it resembled the horse of today? (The bone structure was like the bone structure of the present-day horse—with some differences.) Did they know ahead of time that the fossil bones of the Dawn horse were related to those of the present-day horse? (No.) Here is an opportunity to recall that scientists form hypotheses (educated guesses) which must be tested before they can be accepted.

How did scientists trace the history of Eohippus, the Dawn horse through 60 million years? The children who have read the section with perception can make contributions to this section and to later sections. To start thinking, ask: Where are fossils found? How is sedimentary rock formed? How can we tell the age of sedimentary rock? (Recall the concept of Unit One and the subconcepts in it.)

Sedimentary deposits indicate age of fossils.

Equipment and Materials

. . . 15″ stack of newspapers

How do sedimentary rocks date living things of the past? Stack newspapers to a thickness of 15 inches. From top to bottom of the stack represents 150 million years on a scale of 1″ = 10 million years. What do the layers of newspaper represent? (Sedimentary deposits.) Where in these layers would dinosaurs be found? (6 to 12 or 14 inches down.) Where would the first Eohippus fossils be found? (About 6 or 7 inches down.) What can we infer from the "sedimentary layers" of newspaper (and the textbook description) about when Eohippus first appeared in Earth's history? Further recall of the concepts in Unit One may relate crustal shifts (faulting, folding, mountain uplift) to the location of fossils above lowland regions where sediments (and fossils) can accumulate. Tip the 15″ pile of newspaper to recall how tilting, folding, and erosion can complicate the detective work of fossil hunters.

Extending the Concept

The radioactive record of the rocks. What other check do scientists have on the age of fossils than the way sediments are laid down? The text (page 315) tells of the uranium time clock. You may wish to give a bit of oversimplified information that may help children understand the accuracy by which scientists measure the age of rocks. Let us assume that a present sample of rock has a certain amount of lead and a certain amount of radioactive uranium in it. From complicated studies, scientists know that one half of the amount of radioactive uranium will turn into the stable element lead in about 4½ billion years. By using mathematics and complex processes for calculating radioactivity, scientists can tell how long uranium-bearing rocks have been giving off particles and radiations. To draw an analogy, let children punch with a brad a small hole in a quart carton or a gallon tin, fill it with water, and record the time it takes for half of it to drip out. If it takes 6 hours, how old was it 6 hours ago? If half of a uranium sample is lead, how old is the rock? (4½ billion years.) If a fossil is found in a sedimentary layer, and a nearby uranium rock sample shows that it has been turning to lead for 4 billion years, how old is the fossil? (500 million years.)

Depth of sediment. If it takes 10 years to form 1 inch of sedimentary rock, how many years would it take to lay down the sedimentary layers that have since been laid bare by water eroding the Grand Canyon one mile deep? (5,200 feet × 12 inches × 10 years = over 500 thousand years.) (*Note.* The Grand Canyon was probably slowly uplifted from the ocean floor for millions of years after sediment deposit. It eventually was raised to the height where gullying cut the Canyon to its present depth.)

Horses now and then. Almost every class has children who are fond of horses. Encourage them to compare their favorite mount, by means of drawings, to its Eohippus ancestor. They may also make pipe-cleaner models of the stages in the development of the horse, using modeling clay to show the changes from four toes to a single hoof. Challenge them also to clothe their pipe-cleaner skeletons to represent muscles and hair cover. They should try to explain the changes that helped these early horses survive in changing environments. The American Museum of Natural History in New York has a fine exhibit and descriptive pamphlet of the stages in the development of the horse.

Individual projects. If children did not explore local sedimentary layers when they were studying Unit One, the stimulus of possible fossil discovery may motivate present investigation. Road cuts, quarries (stress safety precautions), excavations (with permission of the contractor) may be sources for locating fossils—or sedimentary layering—by the more ambitious interested child.

Reviewing the Concept

(*Text pages 316–317*)

Before You Go On. A. **1.** a **2.** a **3.** a **4.** a **5.** c

Using What You Know. **1.** On land; it gives more push against solid land. A greater area than a hoof would give more push in water. **2.** Above; the younger forms of life will be found in more recent sedimentary rock layers.

Section 3: LIFE IN THE ANCIENT WATERS

(Text pages 317–322)

SUBCONCEPT

The single-celled organisms that developed in the early seas gave rise to the many-celled organisms of later eras; adaptation to the environment produced more complex structures.

Processes emphasized

Investigation
Observation
Hypothesizing
Theorizing
Prediction

Children deduce, from the fossil record in sedimentary rock layers, that life began in a water environment and that the first single-celled organisms gave rise to many-celled organisms with more complex structures adapted for life in the seas.

Introducing the Concept

How long ago did the last dinosaur live? (About 60,000,000 years ago.) What kind of animals do you think came before the dinosaurs? What kind of environment do you think they lived in? Recall with the children (Unit One, page 44) that the cooling Earth was covered with widespread waters and that the crust of the Earth has shifted upward and downward many times. Four to five hundred million years ago a shallow sea covered the Midwest and there was a coral reef where Chicago now stands. How do we know this? (Fossils in sedimentary rock.) What kind of fossils would you look for in this part of the United States? These fossils lived nearly eight or nine times as many years ago as the last dinosaur did. But there were other living things before them.

What kind of structure do you think the first living thing had? (Single cell.) **What do you think the first animals lived on?** (Plants.) **Would we find fossil animals with backbones in the oldest sedimentary rock layer?**

Developing the Concept

Children begin to develop a sequential pattern for the appearance of the different forms of life.

Vertebrates and invertebrates. If you think your children need to develop the distinction between a vertebrate and an invertebrate, ask: What is a vertebrate? Recall the skeletal system studied in Unit Five. Is a bird a vertebrate? Is a clam? A lobster? A fish? Are you? Which are not vertebrates? What do you think the word *invertebrate* means?

As children read this section of their textbook, encourage them to list the animals named under these headings, for which one example is given:

	VERTEBRATE	INVERTEBRATE
Example:	dinosaur	jellyfish

Can you draw or describe what life was like in ancient seas? Would you expect to find invertebrates in older or younger layers of sedimentary rock? Why was the first vertebrate fossil such a great find? How is a backbone a useful adaptation? Encourage recall of the functions the vertebrae serve (Unit Five).

Children develop understanding of the importance of adaptations of structure to successful survival in an environment.

Equipment and Materials

. . . fish gills from a butcher

Why did fishes become the dominant animals in ancient seas? Which group of invertebrate animals appears to have been dominant in the ancient waters? Which is the dominant group in the waters today? The first fishes appeared about 500 million years ago. What makes a fish so well adapted? Let us study its adaptations by investigating (text page 320). Even a single goldfish in a pickle-jar aquarium will serve. Why are plants needed? What special structures fit the fish to take oxygen from the water? If you can secure fish gills from a butcher, children can note the bright red color in the network of tiny blood vessels close to the gill surfaces. Here oxygen can diffuse quickly into the blood stream and be absorbed by the red blood cells. Recall diffusion of gases through a membrane; oxygen gas is dissolved in the water that passes through the gills and over the filaments. What are some other adaptations? (Fins and tail for locomotion, scales for protection, eyes for seeing, streamlining for speed of motion, etc.)

In conclusion, elicit children's responses to the question of what remains to be found out about life in ancient waters? Even from incomplete fossil evidence, what facts illustrate that animals are interdependent with one another and with their environment?

Extending the Concept

Simple organisms in today's waters. Which have changed the least since ancient times—vertebrates or invertebrates? Flat-bodied plants or plants with upright stems? Interested children might look for invertebrates in an aquarium, along the beach, along a brook or pond, or even in a ditch where algae and protozoans are adapted to these environments. Encourage children to read about ancient forms of life and compare their findings with the descriptions in their reading. Many ancient forms have adapted and survive today. For example, children may be interested to draw comparisons between the trilobites and the nearest living relative, the horseshoe crab.

Looking for invertebrates. Many kinds of invertebrates can be collected from the schoolgrounds and lawn and studied. Some live in a moist environment or have a means of conserving moisture; for example, earthworms, snails, some insects, sowbugs, and members of the spider class. Encourage children to investigate how each organism they find is adapted to its environment.

What can be learned from a skeleton. Clean a fish skeleton and reassemble the bones, or secure a cleaned vertebra from a butcher and look for rough bone surfaces where muscles were attached. These are *muscle scars.* Museum personnel clean bones by boiling or by using the dermestes (or bacon beetle) which feeds on fatty tissue. Placed in a glass jar with a partially cleaned skeleton, the beetles will feed and multiply. In a few weeks, they will have bared the skeleton. If you obtain and plan to use these beetles, keep them in a can of cornmeal. Persons living near the seashore can send bones or complete organisms "to sea" for cleaning. The parts to be cleaned are placed in a wire cage fastened securely to a rock or stake in a tidal area. Crustaceans will usually strip the skeleton in a couple of nights. Any children who practice these techniques should report their procedures. Since structure is related to function, each child reporting should develop the concept of adaptation as fully as he can, relating skeletal structure to function.

(*Text pages 321–322*)

Reviewing the Concept

Before You Go On. A. 1. a 2. a 3. b 4. a 5. b 6. a

Using What You Know. Sharks came earlier than cod. The vertebrate structure is a later adaptation to the environment.

(*Text pages 323–329*)

SUBCONCEPT

Gradual changes of structure in water animals of the ancient seas adapted them for land living.

Processes emphasized

Theorizing
Model making
Reporting (through reconstruction of the environment)

Section 4: THE FIRST STEP ON LAND

Children gain understanding and appreciation of the many changes that took place in ancient seas before living things could exist on land. They also follow the story of the many adaptations that fitted different kinds of animals for successful land living before mammals arose.

Introducing the Concept

You have discovered that life started in the ancient waters. What two conditions do you think would make water a safer place for living things than land? (More even temperature; moisture.) How do you protect yourself from heat and cold or from drying out? Can you do it in one place or do you move about? What structures would an animal of the waters need in order to live on land, even for a short time? (A way to move about; lungs.)

What kind of animal was probably the first to live on land? What changes in structure made the giant reptiles so successful? Why may they have disappeared?

Developing the Concept

Children compare environmental conditions in water and on land, and relate these environments to developing life forms.

Water or land. Although the textbook does not discuss when plants first appeared on the land, you have an opportunity to review several concepts the children have studied earlier. What was necessary before plants could live on land? (Soil.) How was the first soil made? (Weathering and erosion of rocks.) Scientists believe the first true land plants appeared over 400 million years ago, although there is fossil evidence of the existence of plant life on land 100 million years earlier. In terms of interdependence of living things, what kind of life was necessary before animals could live on land?

Why was the first step of an animal onto the land such a great adventure? Encourage children to infer the great differences between land and water environments. Would a single cell be safer in water or on land? (The relatively stable condition of moisture and temperature in the water protects the cell. It also permits the cell to float freely, and it shields the cell from sunlight and evaporation.) How do cells get their food? Review solubility of substances to diffusion.

Children infer some of the structural adaptations of early life.

Crawling out of the sea. Why did crawling out on the edge of the sea require changes in structure as an adaptation to another environment? Tide tables from a newspaper or almanac could be introduced. Compare the difference between high and low tides. Encourage children who have been to the beach to describe how conditions change once every twelve hours. To clarify the concept of adaptation, what changes must have been required for the tidewater animals to survive between high tides? (Outer covering to withstand drying, more rigid structure, means of locomotion over sand and rocks.) What one other adaptation would these animals need to make before they could survive on land? (Some way to take oxygen from the air.) Are there any animals alive today that have adaptations for land and water living? (Amphibians, e.g., frogs, salamanders, toads.)

Equipment and Materials

See text page 324; also the Teacher's Manual for *Classroom Laboratory 5.*

Now encourage children to read the section up to "The King Reptiles Arrive" and plan and carry out the investigation on text pages 324–325. In this way they may check the inferences they have made.

Life of an amphibian. Many classrooms maintain aquaria to show the development of a frog from eggs to tadpole to adult. It is often possible in the spring to find frog eggs in ponds and to culture them. For directions, see pages 10–11 of *A Sourcebook for Elementary Science.* Or, if this project is not feasible, use a flannelboard to show pictures or drawings illustrating the life cycle of a common amphibian. Compare with the giant amphibians on text page 326. Encourage children to bring in pictures of egg, tadpole, and adult stages.

Children observe and study the life cycle of an amphibian.

Equipment and Materials

. . . flannelboard
. . . pictures of amphibians

The Coal Ages. Recall with the children the ancient times in which coal was formed (Section 7, Unit Six). What was the environment like? (Warm, moist.) Why was this environment favorable for huge amphibians (illustrations, text page 326) and the later development of giant reptiles? (Plentiful food.) During the Coal Ages, which lasted for more than 150 million years, amphibians were abundant. The giant reptiles appeared about 200 million years ago and roamed the Earth until about 60 million years ago.

Children analyze the relationship between environment and living things.

The Age of Reptiles. Why do we know so much about dinosaurs? (The fossil record.) *Dinosaur* means terrible lizard. Why? Encourage children to study the illustrations as they complete reading the section (pages 326–27). It is important that children understand our knowledge is based on evidence shared by scientists who have discovered fossil remains in many parts of the world.

Further adaptations led to dominance by the dinosaurs; failure to adapt to changes led to their disappearance.

You may wish to tell the children some of the following measurements to convey the great size of the giant reptiles. Some dinosaurs were scarcely more than a foot high, no larger than a chicken. Some were so huge that a preserved fossil footprint holds 18 gallons of water. How many quart cartons would you have to draw from the tap to fill this print? (Large numbers are generally meaningless to children unless they can tie them to experience.) Dinosaur tracks from different places show us that some dinosaurs walked on their hind legs. Tail prints show where some dragged their long heavy tails. Let children trace, cut out, and compare one of their own footprints with that of a cutout pattern of Tyrannosaurus' 3-toed track (2′3″ by 2′6″). Use the cutouts to compare the distance between a child's steps and the 13½-foot stride of Tyrannosaurus. It is estimated that one of the largest dinosaurs was 75 feet long, 20 feet high, and 40,000 pounds in weight.

Some fossil bones of the huge herbivorous dinosaurs show tooth marks of the carnivorous reptiles. Tyrannosaurus had a huge head and jaws to hold six-inch teeth. Compare these with your own teeth or those of a horse or cow.

Look up the story of finding dinosaur eggs. If you can find a potato about 8″ long and 7″ in circumference, you will have an approximate model of *Protoceratops*' eggs found by a museum expedition in the high, dry Gobi desert of Mongolia.

In view of this evidence, what adaptations did the dinosaurs make that made them more successful than the amphibians? Children should cite especially their tough skin that resists drying, the laying of hard-shelled eggs as a protection to their young, and great size as a protection against predators. Can you think of a way these adaptations would be a disadvantage if the environment were to change, e.g., if temperature changed? What effect might change of temperature have on plant-animal interdependence?

Extending the Concept

What's wrong with this? A fossil hunter found a stone diary in a sedimentary layer with dinosaur bones. It told how a caveman hunted dinosaurs. For dinner his wife gave him an omelet of dinosaur eggs with a side order of Stegosaurus bones. How many false statements are in this story? Children should cite at least five errors or improbabilities which they can challenge with their present concepts of science.

Making a diorama. Encourage individual children to create a diorama of the Age of Reptiles. Light-blue construction paper or water-colored paper may be curved for a background. Use modeling clay for the animals and plants. They may be supported from above with thread. This activity may be supplemented by a visit to a greenhouse to note the general effect of moisture and temperature on green plants. The Coal Ages experienced a similar "greenhouse" effect. The children who prepare the diorama should explain it in detail with others acting as critics or commentators on the accuracy of information.

A cardboard tide pool. Make a cardboard-box diorama to show an underwater view, suspending cutouts or models of the tidal life. Encourage interpretation of tidal life in terms of adaptations to changing tide levels as reported in newspapers or an almanac.

(*Text pages 328–329*)

Reviewing the Concept

Before You Go On. A. 1. a 2. b 3. b 4. b 5. a

Using What You Know. 1. A salamander and a frog are able to take in through their skins some of the oxygen dissolved in water so long as their skins are moist. **2.** Eggs of fishes and salamanders dry out on land and the living egg cell dies. Reptile eggs have a hard shell that retains moisture in the egg cell. **3.** Birds protect the eggs and keep them warm; reptile eggs are unprotected against enemies, cold, or overheating.

Section 5: UP TO NOW

(*Text pages 330–336*)

SUBCONCEPT

The mammals have been more successful in their adaptations than have other forms of living things.

Children begin to see how an even body temperature and protection of the young are adaptations that led to the dominance of mammals among the living things of the present day. These adaptations were brought about by useful changes in the chromosomes of earlier forms of life.

Introducing the Concept

Processes emphasized

Measurement (through charting)
Investigation
Hypothesizing
Theorizing

If you have been keeping a time line of the appearance of living things with drawings or illustrations, ask: "What kinds of animals are missing from the time line?" Or, you and the children have probably accumulated pictures of animals representing the main animal groups you have studied: invertebrates, fishes, amphibians, reptiles, and birds. Scramble the pictures and let the children arrange them in their order of appearance on Earth as the fossil story has recorded it. What adaptations do birds have that make them successful today? (Temperature, flight, protection of the eggs by the parents.) Did any of the earlier forms of life have these adaptations? Is any group of animals missing? As soon as the children think of mammals, ask: What is a mammal? Encourage the children to name or describe adaptations of mammals that are useful for life in the environment. List them on the chalkboard for reference and evaluation.

What were the first mammals like? Why are mammals the most important (dominant) animals on Earth today? How did this come about?

Developing the Concept

Children observe, investigate, and analyze the importance of an even body temperature.

Equipment and Materials

See text page 332; also the Teacher's Manual for *Classroom Laboratory 5.*

Body temperature as an adaptation. After the children have read the section through page 331, encourage them to start keeping a temperature record, following the directions in the investigation on page 332. As a preliminary, if you have a pet reptile available, obtain an oral temperature reading with a kitchen or high school laboratory thermometer. A clinical thermometer is rather fragile for this purpose. Taking the temperature is easier if the reptile is sluggish from cold. If necessary, place it in a refrigerator in a cloth sack for 20 minutes or so. (*Caution:* Extended artificial refrigeration may damage its body tissues or functions.) Compare the reptile's temperature, a child's temperature, and the room temperature.

If you are unable to demonstrate taking a reptile's temperature, encourage discussion and contributions from children's experiences. Is a frog or a snake more or less active on a cold day? Why? Are birds more or less active on a cold day? Why? (A bird's temperature is constant at about 104° F.) Are you? What are advantages of an even body temperature?

Mammals are adapted for the protection and care of their young.

Protection of the young as an adaptation. One characteristic of most birds and mammals is that they protect and feed their young until they are able to take care of themselves. The young of many species are almost ready to care for themselves when they are born. What kind of animals lay eggs? (Reptiles, birds.) What kind of animals have fur? (Mammals.) If children mention the platypus, ask: Is a platypus a reptile or a mammal? They will enjoy trying to puzzle this out. Give a hint: What one adaptation does the platypus have that all mammals have and no other group has? (Milk glands.) Why do you think mammals are so successfully adapted? (The young are protected until developed, cared for by the parents, and have an even temperature.) The perceptive child will see that parental care and protection of the young have much to do with the successful dominance of mammals, especially of man, in the world today.

Children begin to understand the important relationship between changes in structure and function of the body (adaptation) and changes in chromosomes.

How do adaptations occur? Children complete reading the section. Since chromosomes are studied in Section 7 of Unit Four, it may be well to reread this section in review. Why might it take millions of years for a change to appear in a number of animals? For example, is it likely that all the Dawn horses suddenly developed a hoof instead of three toes? Would a change in structure be likely to develop if it were not a useful adaptation to the environment? If a structure did not change and the environment did, how might this affect the animals? Children may draw inferences from the dinosaurs—their great size, drying up of the land, development of more successfully adapted animals, and so on. Stress, of course, that scientists continually change their concepts as they gain more knowledge from investigation.

Make certain children understand that adaptations result from slow changes in chromosomes—in the cells of living things. Adaptations in structure help animals become dominant in an environment, another illustration of the interdependence of living things with one another and with their environment.

Extending the Concept

Preserved in ice. What would you think if you read in the newspaper that a scientific society had dined on steaks a million years old? Is it possible? (Yes, if the meat could be preserved that long.) How do we preserve meat today? Where do we find natural year-round ice boxes? (Glaciers, as in the Arctic and Antarctic.) What kinds of animals might have lived in these regions 2 million years ago? What sort of climate might have been in these regions then? What may have happened to the climate? (It became colder; the mammoths may have frozen to death because they were not adapted to this environment.)

Mammoth meat was discovered frozen in an Alaska glacier, cooked, and served at a banquet of museum scientists in New York City. The mammoth became extinct several hundred thousand years ago.

Preserved in resin and tar. Animals have been preserved whole by being encased in resin (as insects in amber) or in tar (as ancient reptiles, saber-toothed "tigers," and others in the world-famous La Brea tar pits in Los Angeles). Children may enjoy making a miniature tar pit and observing how bones, insects, or other materials dropped upon its surface are coated and preserved. A "pit" can be modeled of sand and soil inside a carton, and filled with tar from a roofing company. Children may model animals found in the tar pits and cut out paper trees to approximate the ancient swamps where the tar welled to the surface. The models may be placed next to the "tar pit" and displayed for others to enjoy.

Oxygen and fossils. Why are fossils preserved so effectively? Recall from Unit One, Section 1, how oxygen combines readily with other substances. Tar and resin keep oxygen from combining with the animals caught in them. Burial in sediment also keeps oxygen away. If fossils are exposed by a change in the Earth's crust and the region is moist, the fossils will be eroded rapidly. Oxygen combines more rapidly with a moist substance. Can you reason why well-preserved fossils are found mostly in arid regions such as the Southwest or the Gobi Desert?

Reviewing the Concept

(*Text pages 335–336*)

Before You Go On. A. **1.** a **2.** a **3.** b **4.** a **5.** b

Using What You Know. **1.** Yes. However, man has been to the top of the highest mountain and to all parts around the South Pole. Mammals do not live there normally. **2. a.** Mammals have an even body temperature; the temperature of reptiles falls with cold weather and they or their eggs will freeze. **b.** The eggs of mammals are inside the mother's body; the young develop there. Eggs of reptiles are laid in the soil; temperature changes and enemies may destroy the eggs.

Section 6: THE MAIN CONCEPT: THE STORY IN THE EARTH

(*Text pages 336–341*)

CONCEPTUAL SCHEME
Living things are in constant change.

UNIT CONCEPT
Living things have changed over the ages.

Children strengthen their understanding that living things change. They review how organisms adapted for life in the environment of ancient waters gave rise to organisms adapted for life in a land environment.

CONCEPT SUMMARY

What conditions made life on the young Earth impossible?

The young Earth. What is the longest rain you can remember? What do you think the Earth would be like after a rain which lasted a thousand years? Probably large areas would be covered by a great lake or even a sea. When was there such a rain that lasted many thousands of years in the history of the Earth? The Earth was very hot then. Was there life on the young, hot Earth? What formed above the Earth as rain drops hit the heated rocks? If children seem unsure how water vapor (clouds)

Equipment and Materials

. . . hot plate
. . . metal skillet
. . . wide-mouthed glass jar

How might you show the sequence in which different forms of life appeared on Earth?

In what sequence did organisms adapted to life in water give rise to organisms adapted to life on land?

forms around the Earth, you may wish to illustrate by sprinkling drops of water on a hot skillet. Hold a wide-mouthed glass jar above the pan to collect the vapor. Condensation occurs faster inside a cool jar.

Development of life on Earth. After reading the section, children may enjoy designing a bulletin board showing the sequence in which living things appeared on Earth. The ages might be depicted as risers in a staircase leading from the single-celled animals to the highly developed mammals of today.

Adaptation and dominance of groups of living things. You may wish to use your time line, or the illustrations children sorted out at the beginning of Section 5, to review the adaptation of each group of animals. A very rough, short, and incomplete approximation of time can be developed on the board with the following chart showing how many millions of years ago certain types of animals appeared, how long they were the dominant group on the earth, the kinds of environment they were adapted to, and the adaptations that helped make them dominant.

Millions of Years Ago	Groups of Animals That Appeared	Millions of Years Dominant	Kinds of Environment Adapted To
over 600	Single-celled animals and simple invertebrates	——	Water
600	Trilobites (invertebrates)	175	Water
500	Vertebrates (fishes)	100	Water
400	Amphibians	300	Water and moist land
300	Reptiles	100	Dry land
150	Birds	——	Air and land
60 to now	Mammals	——	All Earth environments

The kinds of adaptations that made each group of animals dominant may be reviewed in a final column if you find it desirable and useful.

Children should not be encouraged in assuming that these groups of animals died out. Many scientists see a relationship between trilobites and the horseshoe crab, for example. Frogs are related to the giant amphibians, and lizards to the dinosaurs. The fishes are the dominant animals of the waters today and birds are dominant in the air. A more complete reference chart can be found in a high school biology textbook.

(*Text pages 339–341*)

FIXING THE MAIN CONCEPTS

A. **1.** a, d, b, c **2.** Mammals maintain an even temperature; they do not need to keep their skin moist, their young develop inside the mother, the parents give the young care and protection till they can care for themselves; an amphibian has none of these adaptations. **3.** No fossils can be found in igneous rock; it was formed inside the Earth where life does not exist.

B. Children's answers can be checked with the glossary, page 359.

C. **1.** a **2.** a **3.** a

A NEW VIEW OF CHANGE

(Text pages 342–345)

CONCEPT RELATIONSHIPS

Matter changes, energy changes, living things change. Wherever we look, changes take place in our universe; yet, in these changes, the total amount of matter and energy remains unchanged.

This final new view brings together the conceptual schemes and the major supporting concepts the children have studied during the year's work. As they review, they see ever more clearly that the one unchanging concept on which they can rely is that change is the constant order of the universe and, more immediately, of the world in which they live.

NOTE. You may recognize that the term *change,* which is used in discussing the development of living things, means that more complex organisms have evolved from simpler organisms during the two-or-more billion years of life forms on Earth. It also means that some organisms have not survived because their ability to adapt did not keep pace with a changing environment. Change is related to the interdependence of living things and their environment, whether favorable or unfavorable. Our present-day biological forms have evolved because of their ability to survive in changing environments. The mechanisms of biological evolution are based in complex understandings of the interaction of heredity and environment. Why any organism exists today—why we exist—is rooted in many biological changes and adaptations. If this understanding is firmly grasped, the use of the term *evolution* may have value at this point in the child's development.

TEACHING SUGGESTIONS

Motion is a form of change.

After children have read this section, or concurrently with their reading, you may wish to reinforce the major concepts brought together in this "New View of Change."

Are you moving while sitting still on a chair? (In relation to the chair, no; but in relation to space, yes.) In Unit Three, you studied the motion of the Earth and Moon around the Sun. What force pulled the bodies into an elliptical path? (Gravitation.) The stars seem to be in a different position at different times of the year. Why? (The position of the Earth changes as it moves around the Sun. Even the stars move, too, as Unit Seven tells us.) How does knowing this motion of bodies in space help us predict where the Moon will be at certain times, for example? How can scientists predict when to send a rocket to the Moon so that it can land exactly where they want it to—as Ranger 9 did on March 23, 1965? (The changes in motion follow the pattern predicted by Sir Isaac Newton in his laws of Gravitation and Motion.)

The stars are continually changing.

When you sit on the beach in the summer, how do you know the Sun is changing? (Its energy gives you a sunburn.) How is this possible? (The fusion of hydrogen atoms into helium atoms gives off tremendous energy that travels through space.) Is the Sun the only body that gives off energy in this way? (No, all the other stars do.) How do we know? (Evidence obtained by the spectroscope shows that only glowing gases can give off heat and light, i.e., energy. All the stars show that atoms are fusing and giving off energy.) What does this tell us? (The stars are changing.)

The Earth is continually changing.

In Section 6 of Unit Eight and in Unit One, you learned that the Earth began as a ball of hot gases that cooled gradually until the Earth's matter became solid rock, liquid water, and gaseous air. You learned, too, that the Earth and its matter are continually changing. What are some of these changes? How have they been important to living things in the past? How are they important today? Children should be able to cite the work of erosion, weathering, and mountain building in changing the Earth's surface.

Living things have been changing since life first began on Earth over two billion years ago.

How is our knowledge of living things of the past related to changes in the Earth's surface? (As a result of sedimentation and mountain uplift, we can study fossils.) What do fossils tell us? What kind of changes took place in living things as the Earth changed? How did these changes happen? (Chromosome changes.) Is adaptation of structure for life in a changing environment another kind of change? (Of course, slow changes have led to our present living things from Earth's earliest single-celled organisms.)

Changes are predictable.

Now that you have reviewed changes in the Earth and in living things, think of some ways in which we count on change in planning our lives. How do you plan for changes in day and night? In the seasons? How are you changing? Let us look at it another way. Suppose there was sunlight 24 hours a day. How would you be affected? Other living things? Suppose the Earth's matter never changed. If water did not evaporate, how would you and other living things be affected? If nothing could be moved by energy, how would you be affected? Matter, energy, life—all seem to be changing, do they not? Since you know that things change, how does this knowledge help you do things you want to do? That is, how can you use this knowledge to predict what will happen?

In concluding the year's work, you may wish to encourage a debate or a panel discussion on what changes in matter, changes in energy, changes in living things, changes in the universe mean to every other living thing on the Earth. Many questions may arise that will seed interest for the next year's work in science.

ON YOUR OWN: PROBING THE EARTH'S CRUST

(Text pages 346–358)

Purpose

The purpose of this final section of the child's textbook is to offer children opportunity to do extended work in some area of investigation. *Concepts in Science 5* encourages them to explore the rocks in the Earth's crust. The section is largely self-explanatory. One of the best ways to awaken interest is to have, on the science display table in your room, a collection of rocks from your own region. Often such a display may be borrowed from a local hobbyist, a high school or college science teacher, or a regional museum. Likely localities for finding igneous, metamorphic, or sedimentary rock, fossils, and related crystalline substances may be posted if you know of them or as interested children discover them.

Starting the Probe

When to encourage children to begin individual exploration of the rocks around them will depend on your assessment of their interest. Since elementary children are inveterate collectors, their exploration can begin at any time during the year. One good time is during the study of Unit One. Encourage children to find out all they can about each rock or substance they collect. Orderly labeling of the source, the composition of the substance, its structure, and its relationship to other environmental matter will whet interest; a disorderly collection only serves to confuse and discourage.

Displays

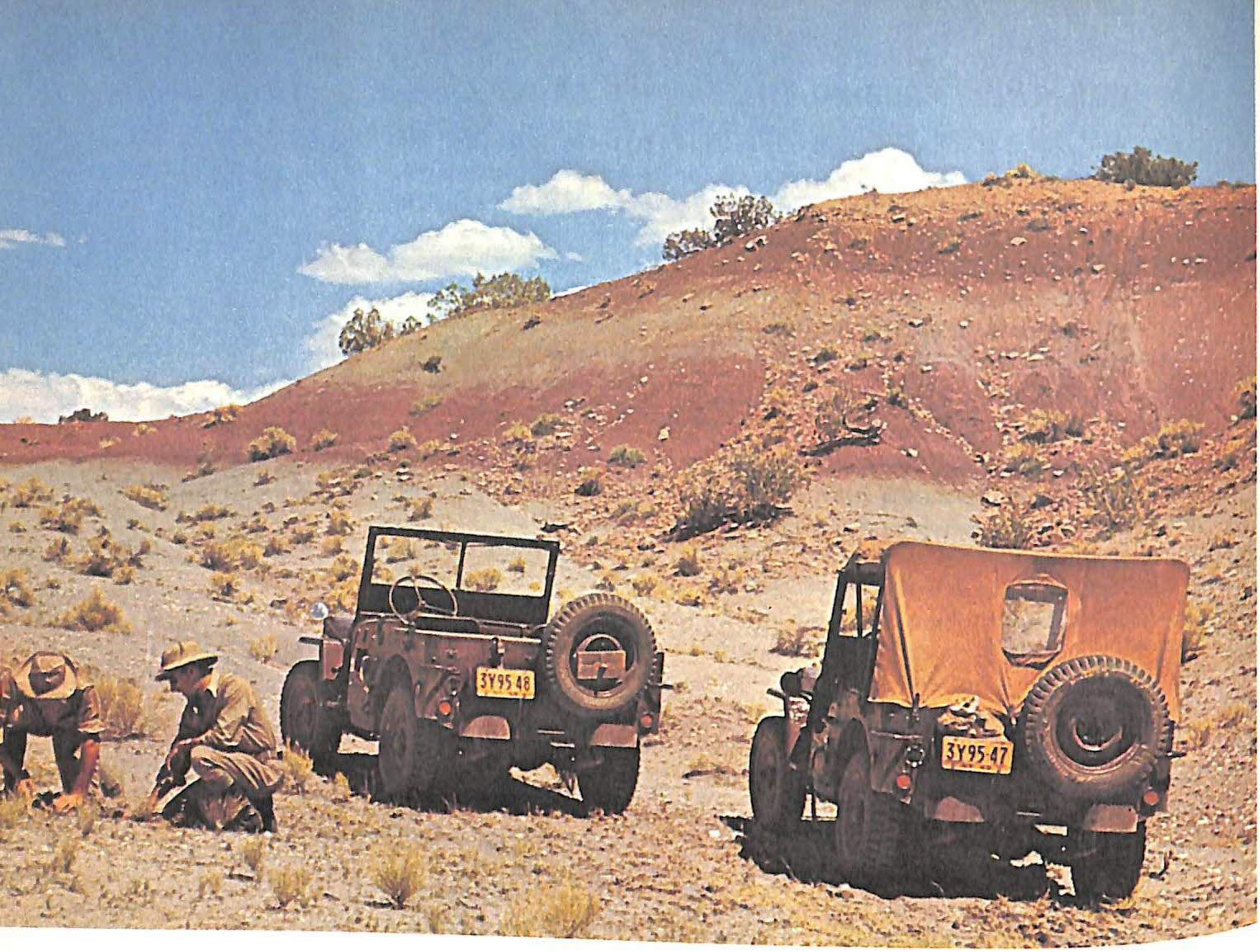
Children who engage in a project thrive on and deserve approbation. Genuine interest should be rewarded by opportunities to display and talk about one's individual work. The science display table and the bulletin board are ideal means for the children's self-expression. Probing the Earth's crust can be a lifetime hobby or a permanent occupation.

Filmstrips

Two excellent filmstrips in full color picturing some of the rocks and minerals and their properties may be used to stimulate interest in rock collecting. The address of the supplier and distributor is on page F–25.

Rocks and Minerals (31 frames), S.V.E., 1959. Colored photography shows principal types of rocks and their formations and gives suggestions for identifying most common rocks. (Primary)

Common Minerals (43 frames), S.V.E., 1962. Beautiful color photography shows characteristics of minerals and identifies them according to scale of hardness. Minerals often occur in form of crystals. (Intermediate)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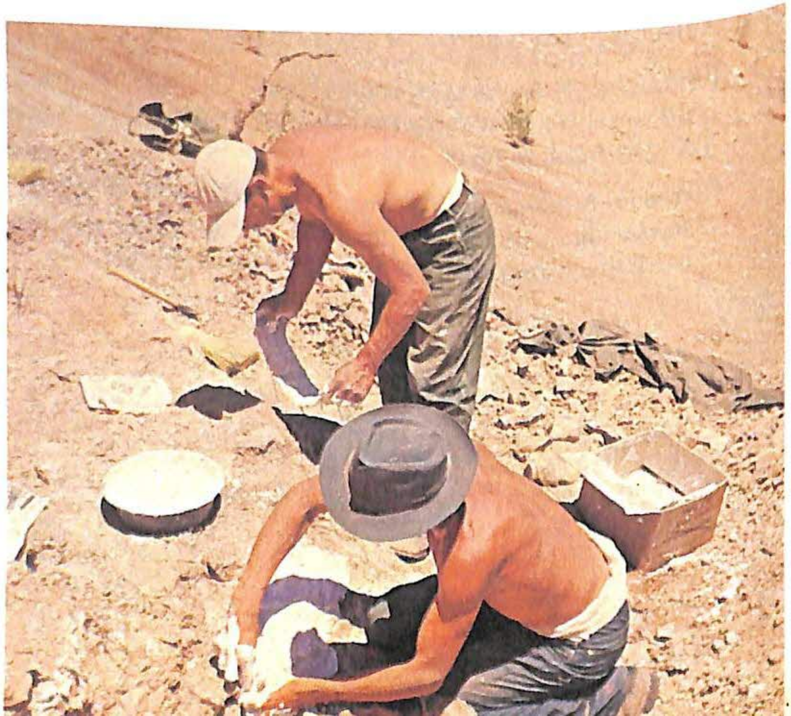


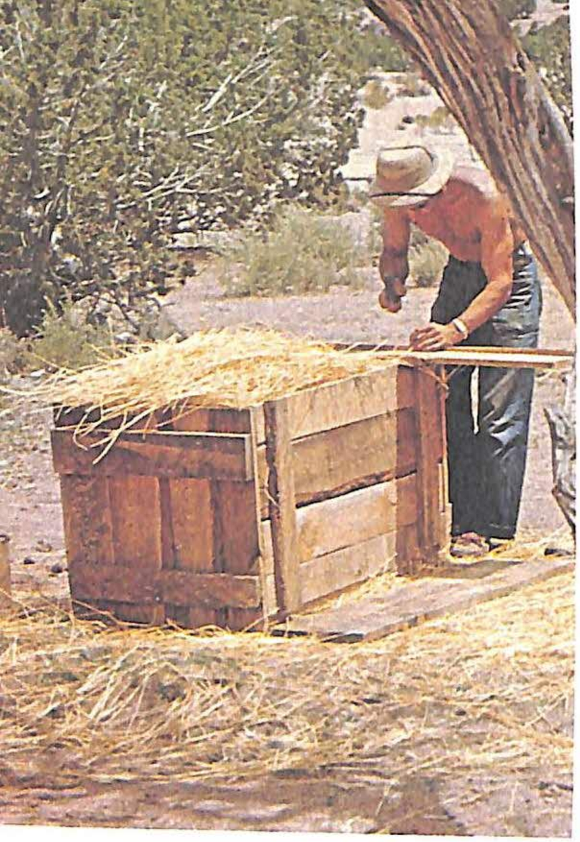
UNIT EIGHT

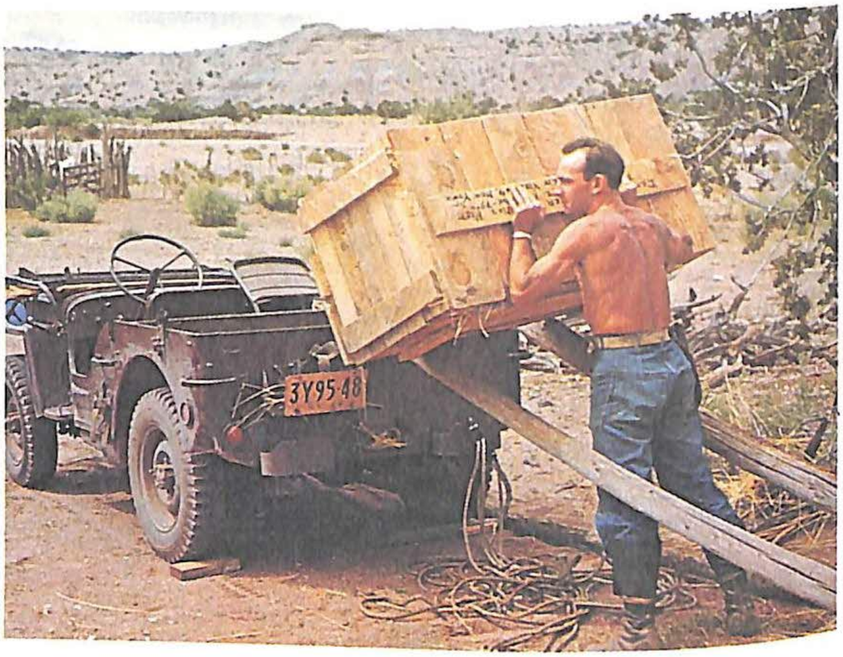
STORIES IN THE EARTH

A scientist was talking to a fifth-grade class.

"A farmer wrote a letter to us at the museum. He told us he had found a strange bone, a bone as long as he was tall. It sounded to us as if he had discovered a fossil bone of one of the huge reptiles, the dinosaurs. We decided that we'd better go and see. So we sent out a team of scientists to look.

"Early in the morning, five of us started to work. We studied the place where the farmer found the bone. Carefully we began to shovel away the soil and pieces of sedimentary rock. Then one digger gave a shout—another fossil bone had been discovered. Now we chipped rock more carefully, and gently brushed away the rock chips so that no part of the bone would be broken. Soon it was lunch time, but no one wanted to stop. By two o'clock we had uncovered three more bones! We stopped at last to eat and to rest. Then we went back to digging.

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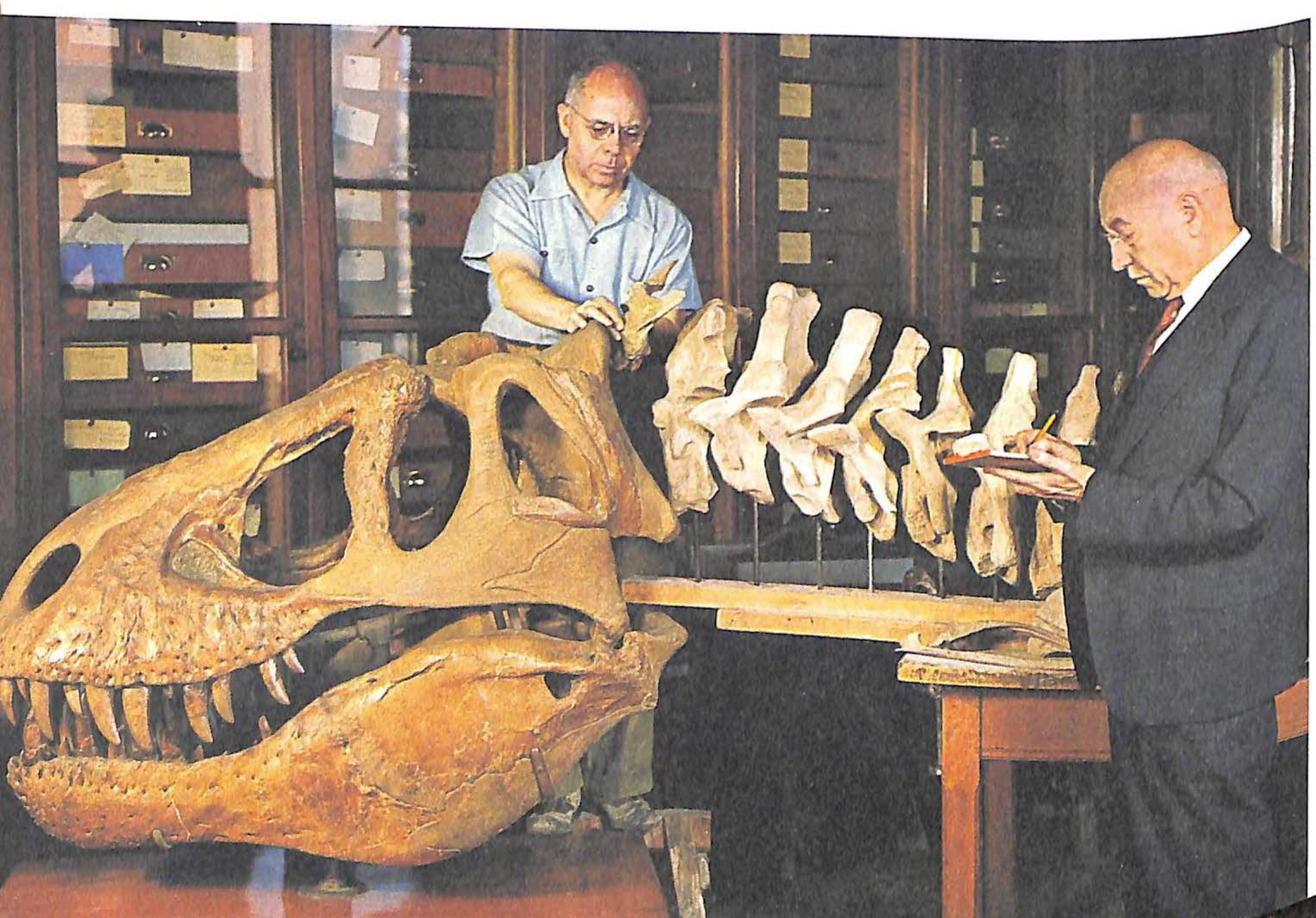


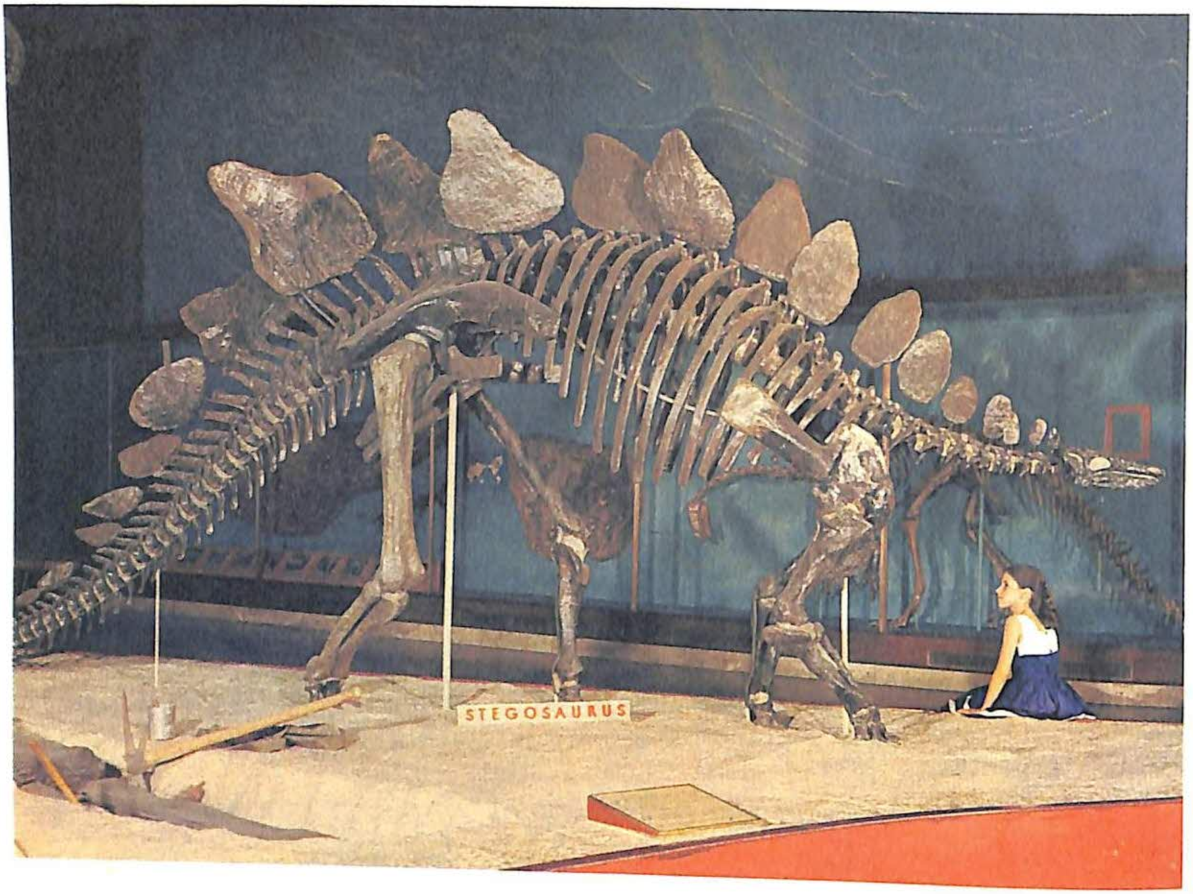
"Whenever we found a bone, we photographed it where it lay. We took many notes—for instance, on how deep the bone was and the kind of rock layer in which we found it. We marked each bone. The marks and photographs and notes help to show us which bones belong where, when we get them to our laboratory.

"We spent several months in that farmer's field and collected many bones. We packed them very carefully for the trip to our laboratory in the museum.

"In the laboratory our real job began, putting the bones together. It was really exciting. What would the animal look like?

"We spent a whole year studying and putting together the fossil bones we found in that field. Some bones were in pieces. We put them together. Some parts were missing. We used plaster to make the missing parts. We could do this because we knew the shapes of the bones. Finally the whole skeleton of the animal was put together. It is quite a fine animal, as you can see from the picture."

As you know, this is one way scientists find out what the Earth was like in years past. And what an amazing story scientists have put together!



1. Bones and Their Meaning

Look at this picture of another animal that fossil-hunting scientists put together. ■ When they were scattered, the bones seemed to have no meaning. When they were studied carefully and put together, the bones became the skeleton of the ancient **reptile** *stegosaurus* (steg′ə·sôr′əs). Stegosaurus was a type of dinosaur that lived on the Earth about 150 million years ago. When stegosaurus was alive, many other reptiles lived on Earth. The dinosaurs disappeared long before men appeared on the Earth. The remains of the dinosaurs, however, became fossils. From these fossils, scientists are building up a picture of the world in which the dinosaurs lived. It was a world of ancient seas where huge sharks and strange reptiles lived and fought. It was a world of ancient lands where great dragonflies, with wings a foot long, flew.

How do scientists go about putting bones together to make an animal they've never seen? To get an idea of how this is done, try putting some bones together. Try the investigation on the opposite page.

AN INVESTIGATION into How Bones Fit Together

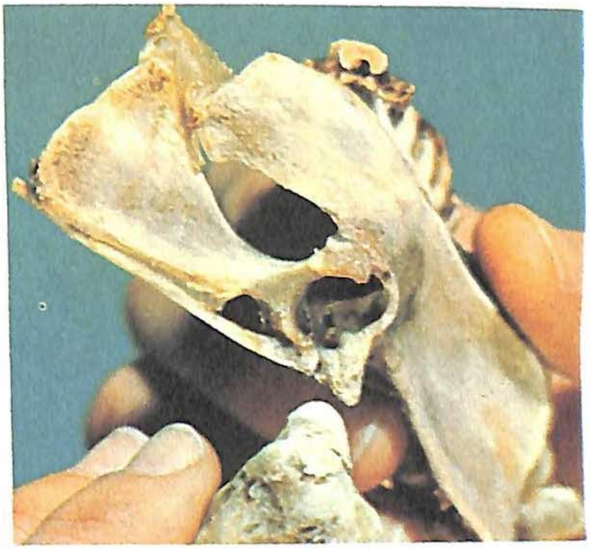
Needed: bones of the leg of a cooked chicken

Next time you have chicken for dinner, save all the bones of a leg. Ask someone to separate the large bones. ■ Then try to put them back together again.

Begin by putting bones that might join together near each other. Do the ends of the bones match? Notice the **ball** on the end of the thigh bone. ● That ball fits into what is called the **socket** of the hip bone. In the same way, the knee bone fits into the socket end of the thigh bone.

The ends of bones fit into each other. ▲ A scientist who has studied living things can use this knowledge to put bones together.

An Additional Investigation: Get the leg bones of a turkey. Clean them off carefully. Assemble the leg bones. If you have time and are interested, assemble the skeleton. To assemble a complete skeleton is a difficult task, however.



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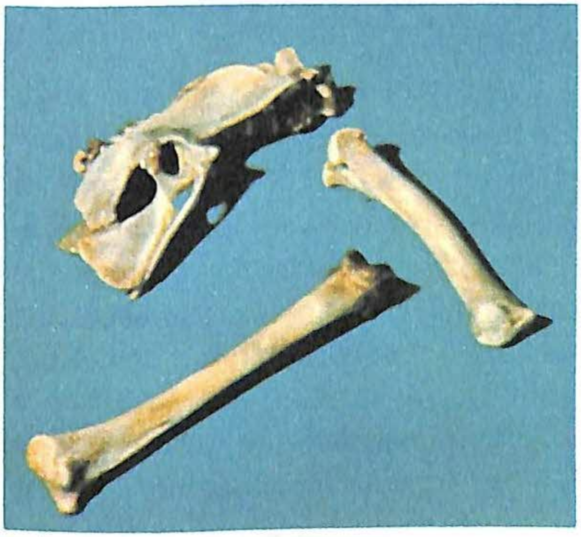

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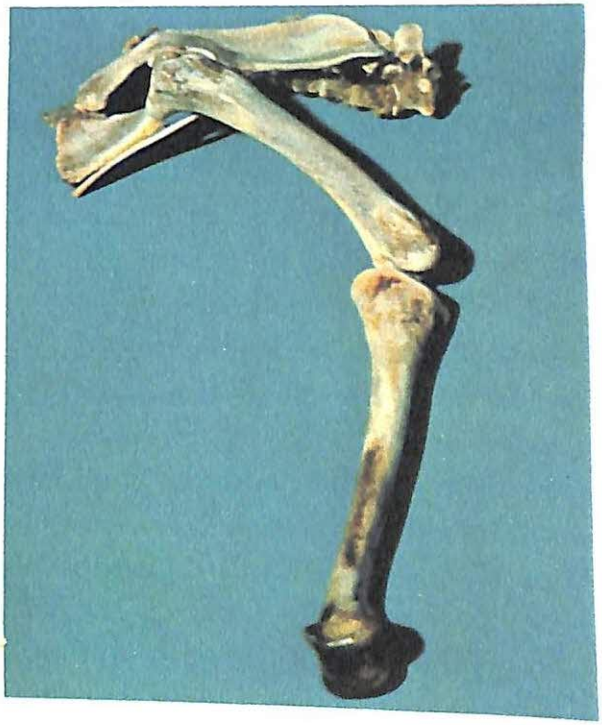

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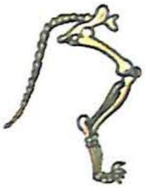

cat

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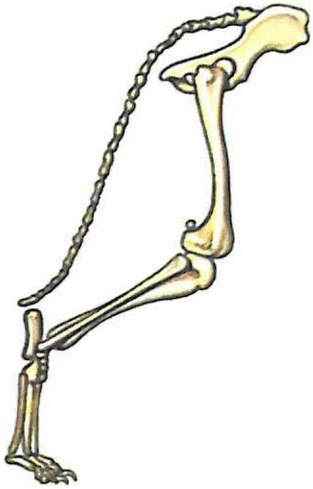
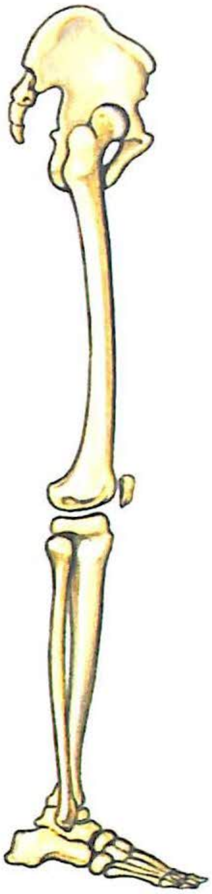


dog



man

The Importance of Structure

The shape of a bone and the way it fits another bone is called its structure. Look at the bone structure of a leg of a cat, a dog, and a man. ■

Observe how neatly the bones fit into each other. Notice how the structure of one bone differs from another, depending on the job each does.

Put your right hand on your left shoulder. Wave your left arm about. Your shoulder has a ball-and-socket joint. Now put your hand on the left elbow joint. Bend the arm up and down. See that the ball-and-socket joint of your shoulder has a different way of working from that of the elbow joint. Each of these joints has a special structure.

Scientists have observed and studied the bone structure of animals now alive to understand the structure of animals which lived long ago. Animals now alive often have much the same bone structure as animals of the past. By knowing about structure, some scientists can put together a whole animal skeleton from a pile of bones. As you can imagine, it takes years of study to learn to do this.

Scientists have been able to put together animals (and plants) from their remains. In this way they have been able to build up pictures of life in the past. Scientists have found the remains of these ancient worlds in fossils. These fossils formed in the sediment that was laid down under water millions upon millions of years ago.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses.

1. Parts of ancient animals found in the Earth are
   a. fossils b. rocks

2. The shape of a bone and the way it fits into another bone is called its
   a. function b. structure

3. Evidence for the kind of living things on the ancient Earth is mainly found in
   a. sedimentary rocks b. igneous rocks

B. Write a paragraph or two on this topic: "How Scientists Know Which Bones of a Fossil Fit Together."

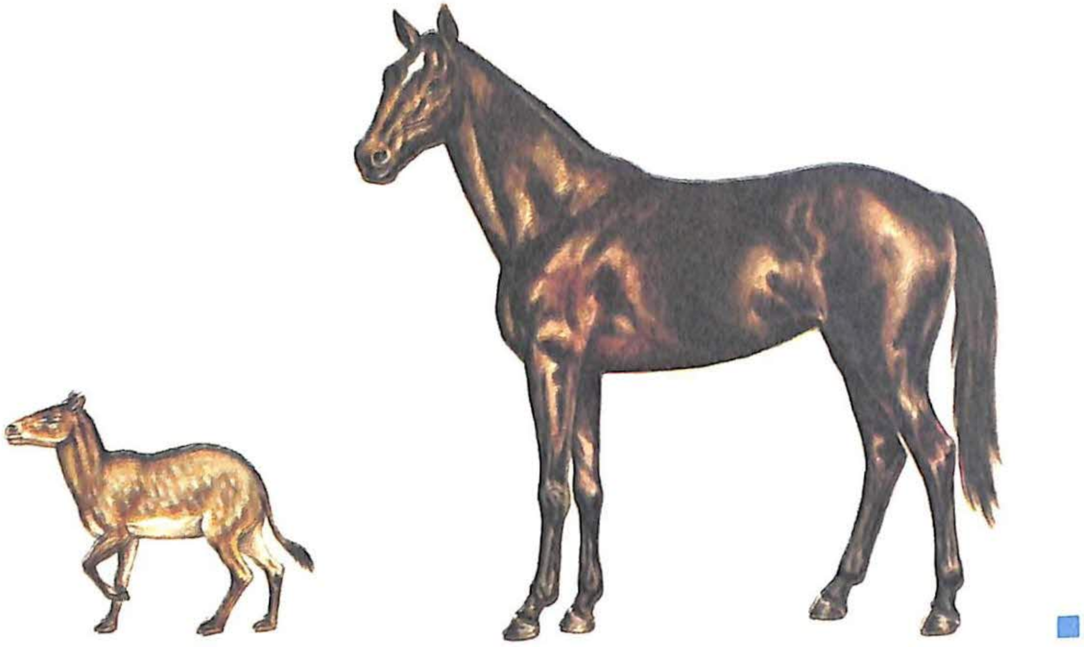
ON YOUR OWN

1. Ancient ferns often formed coal. If you live near a coal yard, ask a foreman if you can look for fossil prints in the coal. Collect these fossil prints and learn to know some of the plants that lived about 300 million years ago.

2. Why not make a collection of models of fossil animals? You may make them of plaster, or soap, or perhaps whittle them out of wood. The pictures in this section of the book may help you in making your models. Plastic model kits of ancient animals are helpful for learning about bone structure.

If you live near a museum, you may be able to make models of real fossils. You and your classmates might enjoy making a little museum of fossil animals and plants.

3. *The Fossil Book*, by Carroll Lane Fenton and Mildred Adams Fenton, published by Doubleday, New York, 1958.



2. Only Sixty Million Years Ago

Certainly these animals look quite different. ■ The small animal is about the size of a fox. Notice its toes and its front legs. Now notice the legs and toes of the fine racehorse. The legs of the racehorse are sturdy. Its hooves can travel fast over rough ground. It can carry a man.

Strangely enough, the small animal is also a horse. However, it lived about 60 million years ago. This small horse changed slowly into the horse we know today. It took about 60 million years for this to happen.

Here is how some scientists pieced the story together.

The story begins with the discovery of some fossil bones. When scientists had put the bones together, made a skeleton, and clothed it as if it had muscles, skin, and hair, they saw a small animal like the one pictured.

How do scientists know the animal looked like this? Hunters of fossils are great detectives. They can build an entire animal from bones. By studying the structure of living animals, scientists know how much muscle a bone can carry. A small bone doesn't carry as much muscle as a large bone. Little by little, a picture of the animal is built up.

This animal turned out to be a kind of horse. It was the beginning, or dawn, of the horse. Scientists call it *Eohippus* (ē·ō·hip′pəs), the dawn horse.

As soon as the first dawn horse was found, the search was on for more. Scientists searched sedimentary rock layers like the layer in which the dawn horse had been found. They found other fox-sized fossil horses in that kind of sedimentary layer. In this picture the dawn horse sedimentary layer is called layer A.

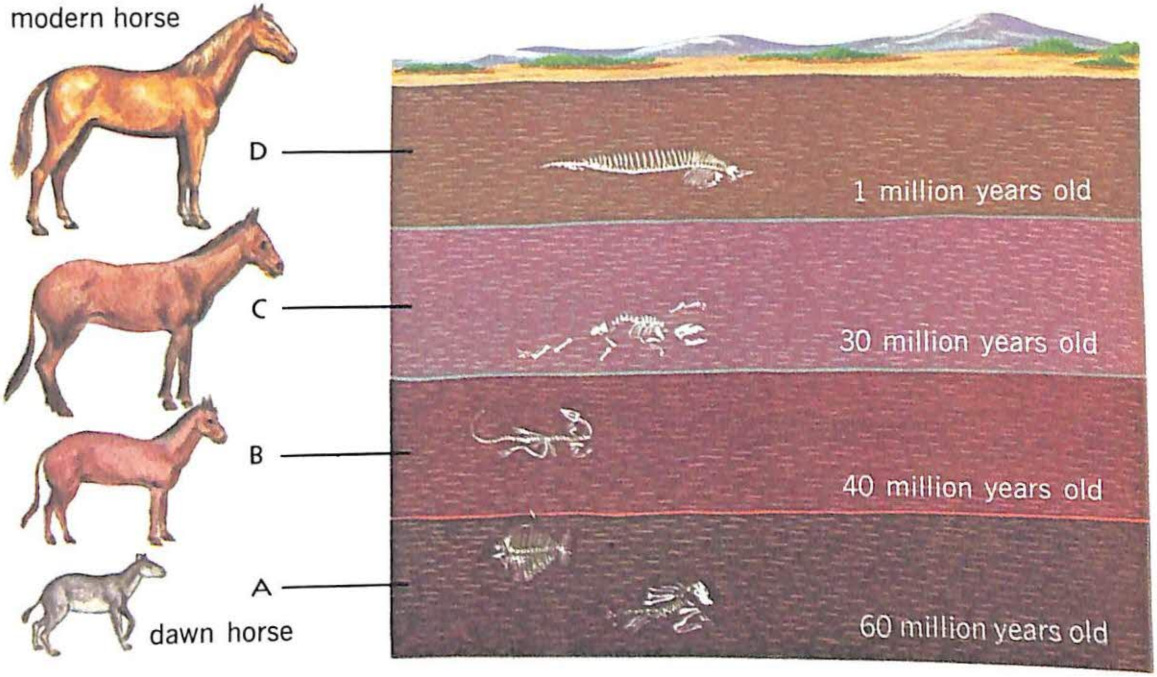
Scientists searched the *next* sedimentary layer, the one laid down *on top of* layer A. It is layer B in the picture. There they found more bones of horses. But these horses were larger than the dawn horses! More than that, these horses walked on three toes. The dawn horse had walked on four toes.

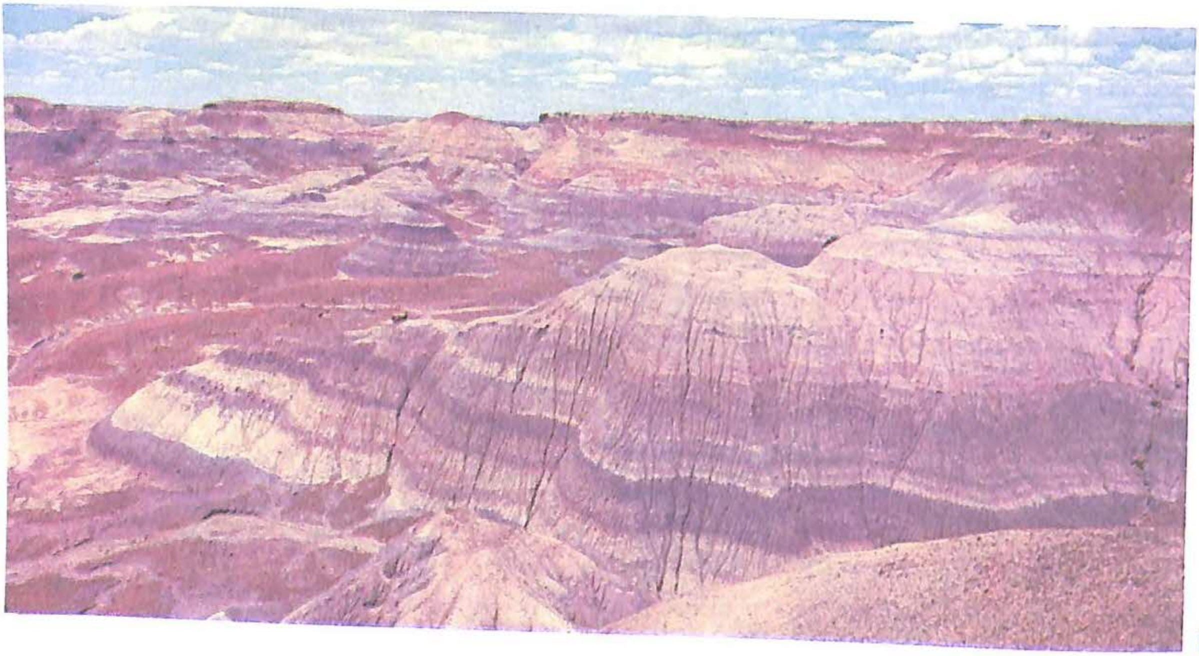
As they searched the sedimentary layers from oldest layer (A) to youngest layer (D), fossil-hunting scientists found larger and larger horses. The smaller horses were found in the older layers, laid down long ago. The larger horses were found in the younger layers, the layers laid down more recently.

What did all this mean? It meant something simple but astonishing. *It meant that the horse had changed over the years.*

In 60 million years, the horse changed from the size of a fox to the horse we know today. It changed in other ways as well, as the pictures show. Notice how the head changed. Did it become larger or smaller? Look at the feet. The dawn horse's four toes, over millions of years, changed to three. Then they changed to two toes, and then to a single toe—a hoof.

Try this. Put your hand on a table. Raise your hand until only the nail of your middle finger rests on the table. Now your hand and arm are





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supported on that nail. Perhaps something like this happened to the horse. Over the years, the front foot of the changing horse seems to have lifted up on the middle toe and rested on the nail. The hoof of a horse is a kind of thickened nail.

This has been the story of how one kind of animal changed. Scientists have been able to uncover many other stories, showing changes in many other animals, and in plants, too. Fossils of camels have been found in Wyoming. They show that the camel was once the size of a sheep! We know that the elephant was once very different from the elephant of today. Birds were different from the birds of today. So were the reptiles.

How do we know how long ago these fossil horses lived? Let us see how we determine the age of a fossil.

The Age of a Fossil

Look at these layers of sedimentary rock. ■ Can you tell one layer from another? Yes, for one sedimentary layer does differ from another.

Some layers contain substances which are colored red, or yellow, or brown. Different chemical elements and compounds color the sediment. Iron compounds, for instance, may color sediment red. Soil has color. There are red soils, black soils, brown soils. There are sands of different colors, as well. So sedimentary rock layers may be colored differently. The structure of the layers may be different, too.

To know which layer is oldest, you must know which was laid down first. If the layers are in the order in which they settled down, then the bottom layer is the oldest.

Still, how can scientists find out how *old* a rock is? There is an interesting answer.

Scientists have discovered a kind of clock in the Earth. As you learned in Unit One, the element uranium in the Earth is slowly turning into lead. How fast uranium changes into lead has been found out too. So the substance uranium is a kind of clock, keeping time in the rocks. The uranium clock doesn't tell time in hours, however, like an ordinary clock. It tells time in millions of years.

Suppose a fossil-hunting scientist finds a piece of rock with both uranium and lead in it. He knows which lead in the rock came from uranium. He can figure out how long it took for uranium to change into that much lead. Since the uranium began changing when the rock was formed, he knows about how old the rock is.

From the uranium clock, and from other evidence, scientists have an idea of how old the Earth is. The Earth is at least $4\frac{1}{2}$ billion years old. It may be older. Some scientists think it may be 10 billion years old.

Here is another way of finding out the age of a rock. Sometimes scientists can discover how long it takes for sediment to become sedimentary rock. For instance, in a certain place sediment may take 500 years to form 1 inch of rock. Suppose that the rock is 1,000 inches thick. Then it must have taken about 1,000 times 500 years to form, or 500,000 years.

Scientists do have ways of finding out how old sedimentary rock layers are. *When the age of a sedimentary layer is known, then the age of the fossils in the layer is known too.* This is how scientists know that the dinosaurs pictured on page 327 lived about 150 million years ago, and that the dawn horse lived about 60 million years ago.

Finding the age of a rock layer isn't always easy. Sometimes the Earth's crust heaves up and the sedimentary rock layers are lifted, split apart, tilted. ● Huge pieces are sep-

●

arated. The layers are no longer in order or in the place where they were laid down. Even so, scientists may manage to fit the puzzle together.

No man ever saw the dawn horse alive. Yet we know that 60 million years ago the dawn horse roamed and grazed in the forests of what is now North America. We know this is true from the evidence of fossils that many scientists have found in sedimentary rocks.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The modern horse came from an animal that was about the size of

   a. a fox b. an elephant

2. Scientists can build up an entire animal from a few bones because they have studied animal

   a. structure b. environment

3. The older sedimentary layers have in them animals that came

   a. earlier b. later

4. Scientists may be able to tell the age of a rock layer by means of the element

   a. uranium b. germanium

5. From their studies, scientists think that the age of the Earth is at least $4\frac{1}{2}$

   a. thousand years
   b. million years
   c. billion years

B. Write a paragraph or two on one of these topics: "The History of the Horse," or "How We Tell the Age of a Fossil."

USING WHAT YOU KNOW

1. Examine again the pictures of the change in the hoof of the horse. Is the hoof most useful on land or in water? Why do you say so?

2. The fossils of a certain fish are generally older than the fossils of a certain amphibian.

Would you expect to find the fossils of these amphibians in sedimentary layers above or below those of the fish?

ON YOUR OWN

1. Many museums have collections and exhibits of fossils. Why not visit one?

2. For your reading: *Prehistoric World*, by Carroll Lane Fenton, published by Doubleday, New York, 1954. You may be particularly interested in the account of the early horses. The early history of the camel is told also.

3. Life in the Ancient Waters

We can go back in time still further.

Let's go back before the dawn horse, before the dinosaurs, when there was no life at all on land. However, there was life in the waters. From sedimentary rocks and the fossils found in them, scientists are putting together pictures of life in those ancient waters.

The early living things that dwelt in the waters may have looked like these single-celled animals and plants. ■ There were no cod or salmon, no porpoises or whales. Only very simple, single-celled living things swarmed in the warm waters, at first.

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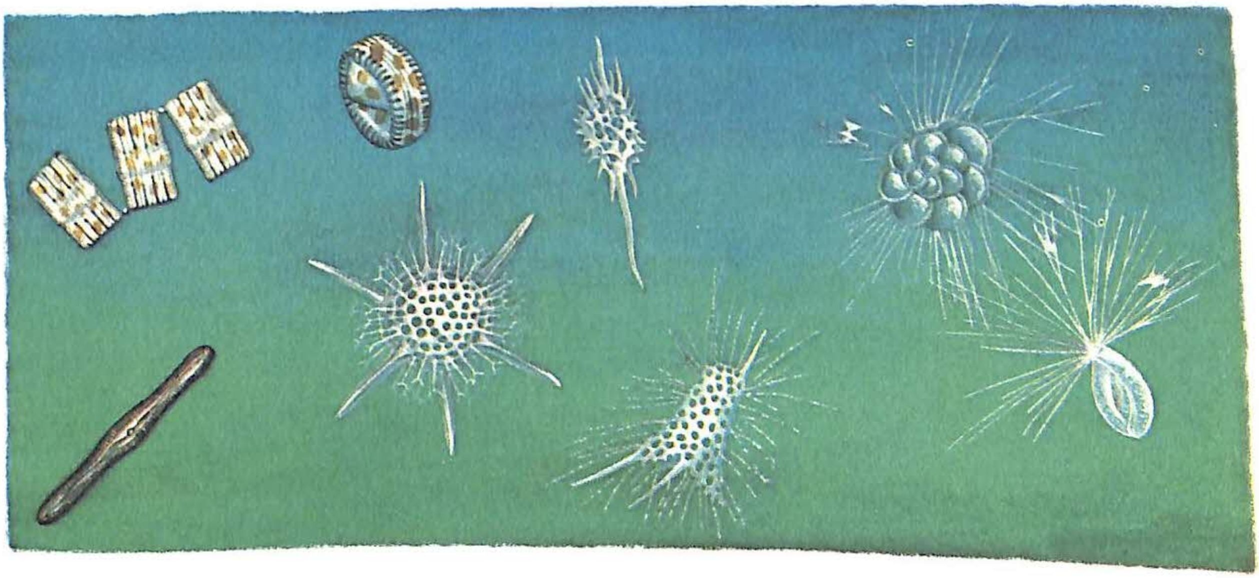
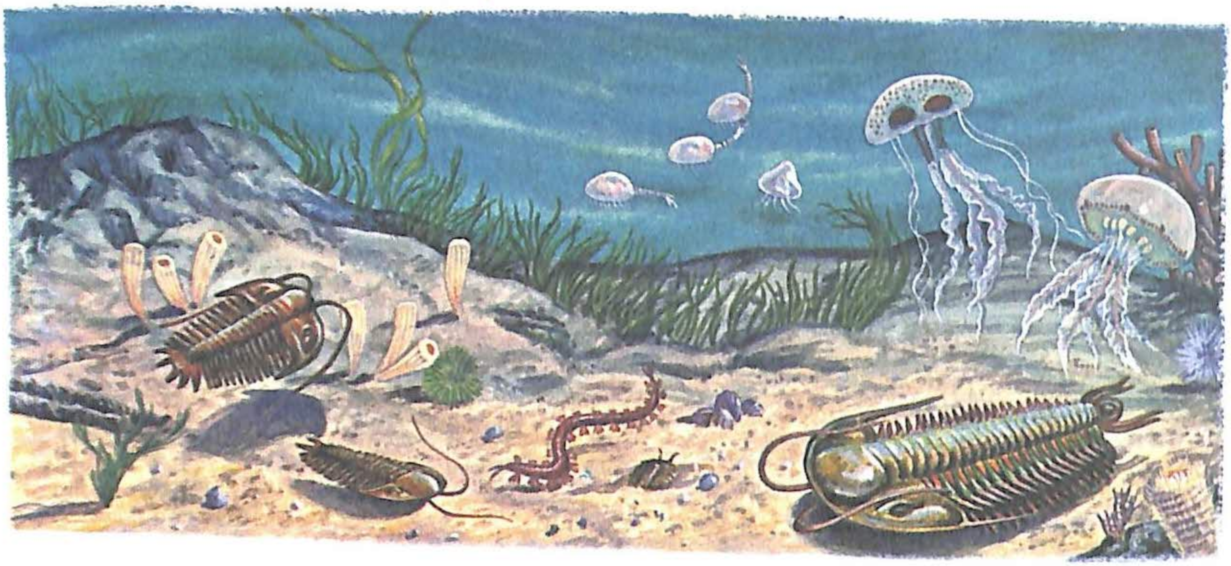
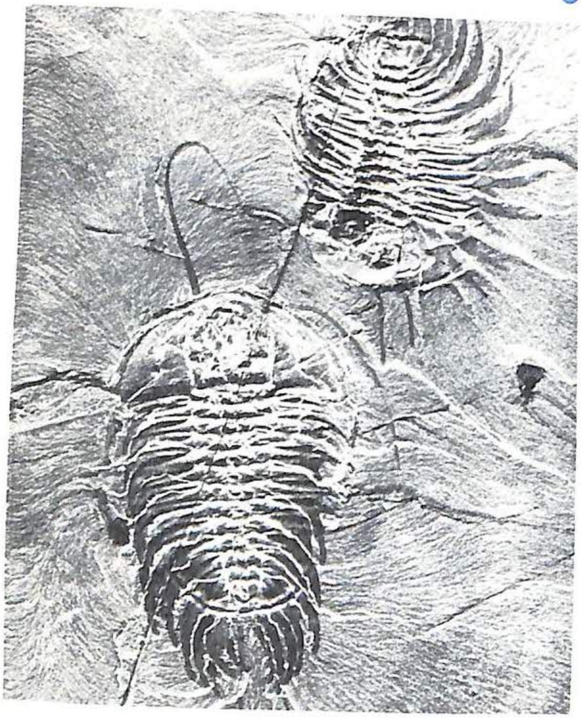




Somehow from the simple, single-celled animals came the larger, many-celled animals. (Scientists have an explanation, as we will see later.) So in time, the seas held not only single-celled living things, but many-celled living things. There were sponges, jellyfish, and many kinds of wormlike animals. ■ These were all animals without backbones, or **invertebrates** (in·vûr′tə·brits).



There was also a strange animal that is no longer around. It was the *trilobite* (trī′lə·bīt). The trilobite, too, was an invertebrate (without a backbone), in spite of its bony appearance. ●

There must have been a time when the ancient waters were almost crowded with trilobites. Scientists are fairly sure of this because some ancient sedimentary rock layers contain many fossils of trilobites.

A Backbone Appears

In the older layers of sedimentary rock the fossils are all invertebrates, all without backbones. There were invertebrates that we know today; clams, starfish, and huge squidlike animals.

Then, in a higher layer of rock, there was a great find. It was the fossil of an animal with a backbone, a **vertebrate!** This vertebrate was a fossil fish, not more than a foot long, called the *ostracoderm* (os′trə·kō·dûrm). Unlike any fish alive today, the ostracoderm was covered with hard plates of bone.▲ This small, ugly, armored fish is important because ostracoderms may have been the ancestors of the different kinds of fishes we know today.

The fishes in the early waters were not as they are today. But the ancient fishes lived much as fishes do today. They fed on smaller fishes and invertebrates. Most of all they fed on the green, red, and brown sea plants. These flat-bodied plants have changed little since ancient times. The plants of the sea haven't changed as much as the animals.

The story of the ancient waters that scientists are piecing together seems to be this.

In those ancient seas, single-celled animals gave rise to many-celled animals. The earliest many-celled animals were invertebrates. There were jellyfish, starfish, crab and lobsterlike animals, clams, and squid.

Somehow, in those ancient waters, one kind of invertebrate gave rise to a vertebrate. From this vertebrate came the early **fishes.** The early fishes were the earliest vertebrates. The armored fishes gave rise to the bony fishes. These bony fishes were not very different from the fishes found in our waters today.

Fishes are particularly fitted to live in water, or adapted to live in water, as scientists say. Indeed, fishes are so well adapted to live in water that they have become the main vertebrates of the sea. Why were the fishes successful in becoming the main vertebrates of the sea? You can study their adaptations, or fitness for life in the water, in the investigation on the following page.

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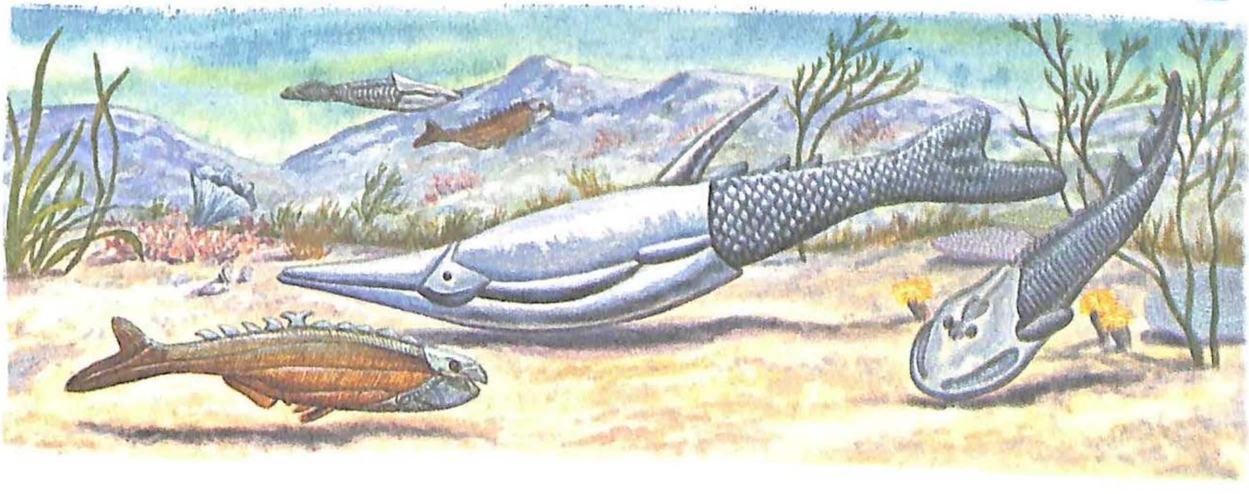


AN INVESTIGATION into the Adaptations of the Fish

Needed: an aquarium tank or fishbowl, sand, water plants, goldfish or guppies; if possible, water from a pond, well, or stream

To prepare an aquarium, put about 2 inches of sand on the bottom of the tank or bowl. If pond or well water is available, add it. The water level should be at least an inch below the top of the tank. Let the sand settle, then plant the water plants as shown. ■

If you must use tap water, let it stand in the tank for a week before the plants are added. Tap water may have chlorine in it, which will pass off in this time.

After the plants have been put in place, let the aquarium stand in medium light for another week. Then you can put in the fish. A fish about an inch long requires about a gallon of water. Feed the fish a pinch of food every 2 days.

How is the fish adapted for life in the water? Here are four life activities.

movement
getting food
getting air
reproduction

How is the fish adapted to carrying on these life activities in its special environment? Some of these activities can be investigated by observing the fish. Others may call for other methods, such as reading and discussing with those who know.

It may be best to write your observations in a notebook.

Additional Investigation: If you live near a pond or stream, you may be able to add to your observations there. What will you find?

■

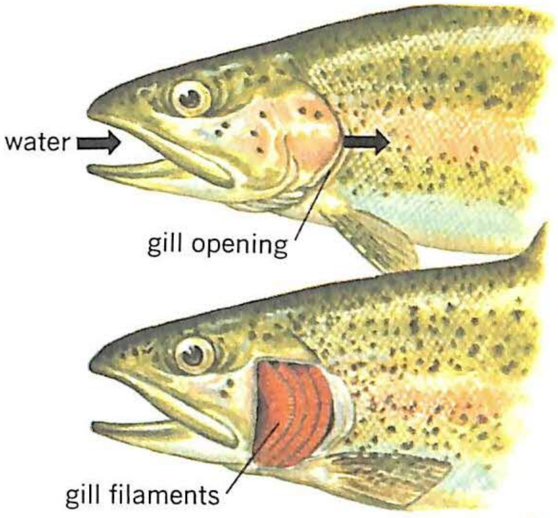
The Fitness of a Fish

Observe a fish and you will see that it is adapted for life in the water. Its form glides easily through the water. Its fins and tail push it through the water. Most important, the fish can get oxygen from the water. For there is oxygen gas dissolved in water. Let a glass of water stand, and soon bubbles of air that was dissolved in the water appear. A fish gets its oxygen from such dissolved air.

The fish takes oxygen from water by means of its **gills.** ■ The fish gulps in water through its mouth. As the water passes over the gills, oxygen enters the gill filaments. Then the water flows out through an opening like a slit. The opening is usually covered by the gill cover.

Thus the fish is adapted to life in water by its structure. It is the structure of an organism which adapts it for life in its special environment.

The fishes of the ancient waters had adaptations for water life. These adaptations made the fishes very successful animals in their environment. Soon they filled the ancient seas.



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However, there is still much to be known about life in the ancient waters. There is still much to find out. For instance, scientists don't know just how these changes happened. They do know that these changes took millions of years. The fishes didn't appear suddenly. Other animals gave rise to the ostracoderm. Then the ostracoderm changed slowly.

Many pieces of the puzzle are still missing. However, from the evidence we have, this much is clear. *Life has changed during the millions of years it has been on Earth.*

BEFORE YOU GO ON

A. Study these statements and choose the correct responses.

1. The earliest living things lived
   a. in water b. on land
2. The earliest living things were made of
   a. only one cell b. many cells

3. Of these two groups of animals, the one which came later was

a. the invertebrates b. the vertebrates

4. The older sedimentary rocks contain the

a. older fossils b. younger fossils

5. The earliest vertebrates were the

a. sponges b. fishes

6. To be adapted to an environment means to be

a. fitted to it b. born in it

B. Write a paragraph or two on this topic: "Ancient Life in the Seas."

USING WHAT YOU KNOW

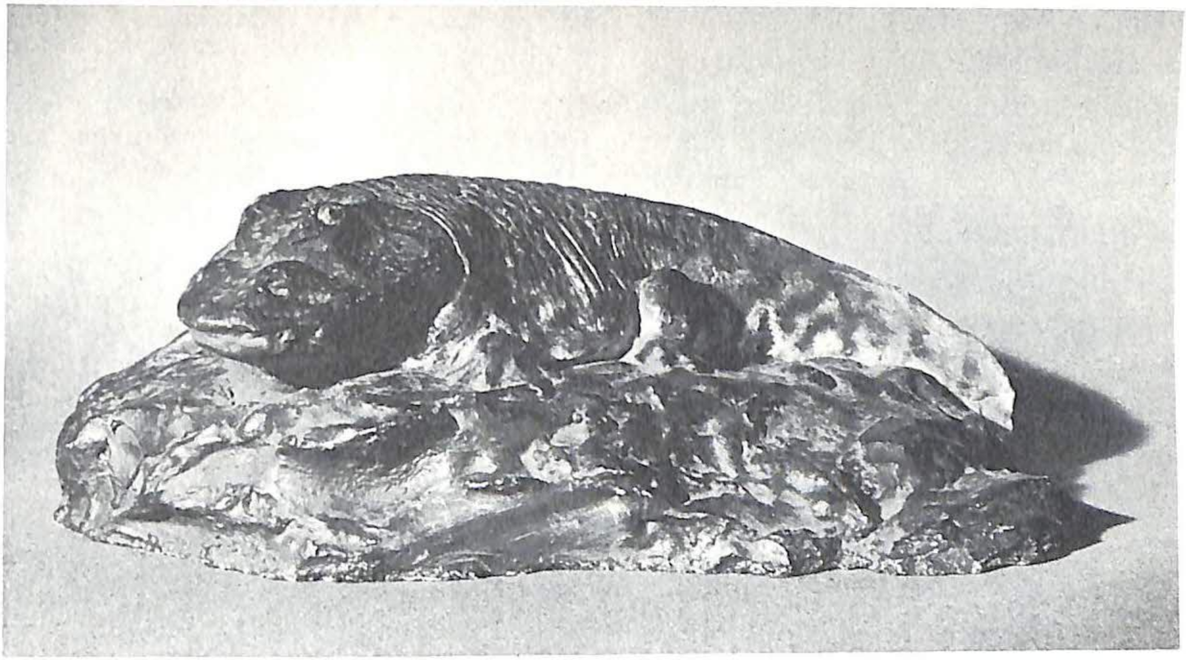
Bone develops from cartilage. The bones of a newborn child are soft. They have cartilage in them. Later the cartilage will become hard bone.

The early fishes may have had skeletons of cartilage. Sharks have skeletons of cartilage. Cod have skeletons of bone. Which do you think came earlier, fishes like sharks or fishes like cod?

ON YOUR OWN

1. *What Is a Fish?* by Gene Darby, published by Benefic Press, Chicago, 1958. You may want to study more fishes. Here is a book that will help you to learn more about different kinds of fishes, and it will also help you to take better care of fish.

2. *Experiments with a Microscope*, by Nelson F. Beeler and Franklyn M. Branley, published by Thomas Y. Crowell, New York, 1957. If you have a microscope, you may want to study the microscopic living things in pond water. One way to keep these living things growing is to collect pond water in one-quart jars. Fill each jar about three-quarters full. Then add ten grains of rice. The rice will decay as bacteria feed on it. The single-celled animals in the pond water will feed on the bacteria.



4. The First Step on Land

Long, long ago a sea animal left the water for the land. It was probably a fish of some sort. Of course learning to live on land didn't happen suddenly. It took millions of years. Even so, it was a great adventure, for surely the water was a safer place to live than the land.

From Water to Land

One reason why the water is a safer place than the land for living things is that *water changes temperature slowly*. Animals and plants living in the seas are fairly safe from boiling or freezing. Animals and plants on land may have to stand burning heat in the summer or icy cold in the winter. When the Sun's heat is too great, animals and plants on land may dry out. Have you ever seen a field of parched corn? Drying out is dangerous for living things. Plants and animals in the sea do not dry out.

In spite of that danger, the adventure happened. Sometime in the ancient past, a kind of fish developed some kind of way to crawl out on land. More than that, this fish was able to do something most fishes cannot do. Somehow it was able to breathe air.

What a strange creature the first land animal must have been! Fossil evidence makes scientists think that the creature may have looked part fish, part salamander. ■ No such animal is alive today. However, there are fishes now alive which crawl out on land and breathe air for a short time, like the lungfish.

Does it surprise you that water may be safer than land? The investigation opposite will give you a clue as to why this is so.

Early Life on Land

In an early age the land was not as dry as it is now. The early land was moist and warm. Ferns as tall as trees grew in it. They shielded animals on the land from the Sun's heat.

Do the animals shown at the top of page 326 remind you of any animals living today? These early animals were **amphibians**, animals living both in water and on land. They look like clumsy salamanders, don't they? They were huge, however. Many of them were armored.

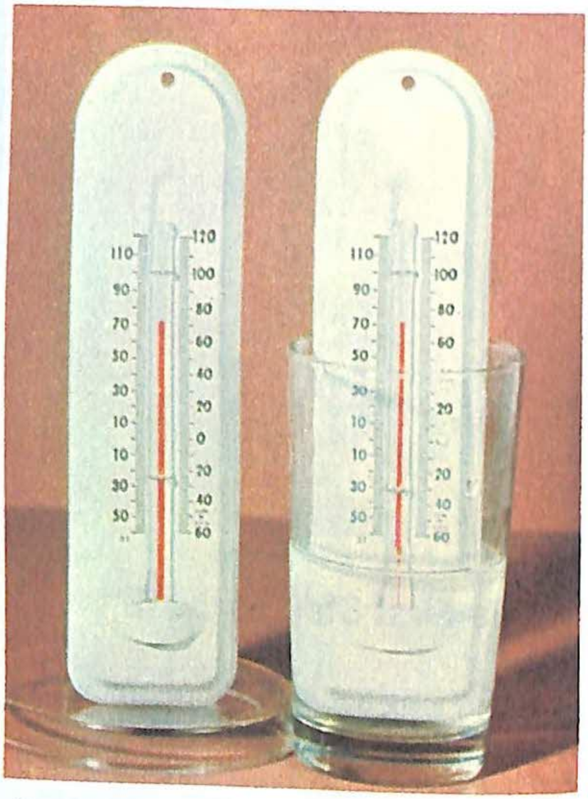
Food was plentiful in those ancient fern forests. Great insects swarmed among the leaves. Huge worms had found their way from the water to land. For many millions of years the amphibians lived in the warm, moist forests and were kings of the land. But the amphibians did not rule for long.

The King Reptiles Arrive

Nothing remains the same. The Earth changes. Plants and animals change.

As millions upon millions of years passed, the amphibians changed. There came amphibians whose bodies could stand more drying out. They had tougher skin. They could wander

AN INVESTIGATION



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Needed: two thermometers, a watch or clock, a glass of water, sunlight or a hot radiator, and a refrigerator

Put one of the thermometers in the glass of water. Now you have a thermometer in air and a thermometer in water. Place them both in a cupboard or closet and leave them there until they have reached the same temperature. (It will be the temperature of the air in the room.) Here is what happened in one trial. ■

Now put the thermometer-in-air and the thermometer-in-water in the sunlight, or over a hot radiator, for just 3 minutes. Which thermometer shows the

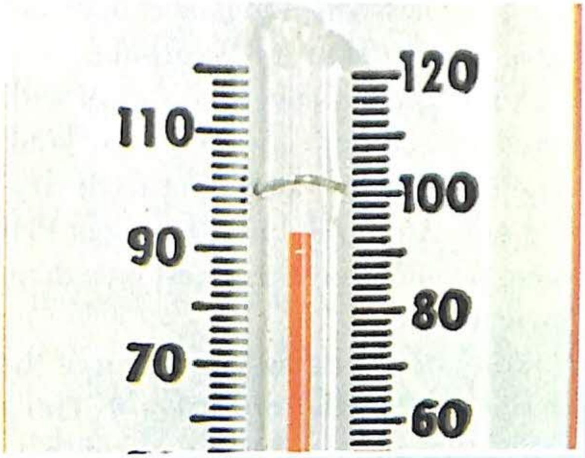
into Why Water Is a Safer Shelter Than Land

greatest change in temperature? Here is what happened on one trial. ●

Return the thermometer-in-air and the thermometer-in-water to the cupboard. Let them reach the same temperature again. Then place them in the refrigerator. At the end of 3 minutes which thermometer shows the greater change in temperature? Here is what happened in one trial. ▲

Why is water a safer shelter than land?

Additional Investigation: Take the temperature of a pond or lake every day, and compare it with the temperature of the air. Do these observations agree or disagree with the results of the investigation above? Is the pond water a safer shelter than the land? Why?



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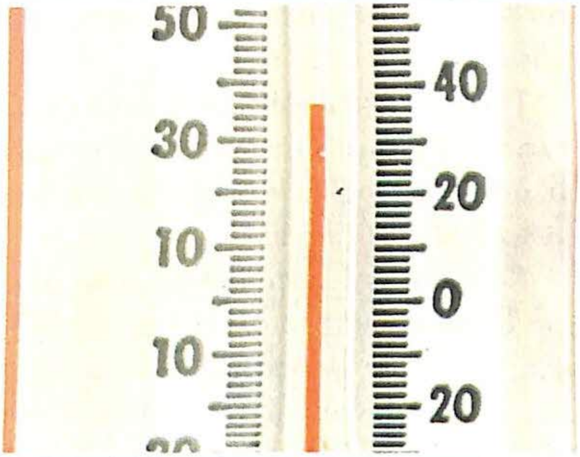

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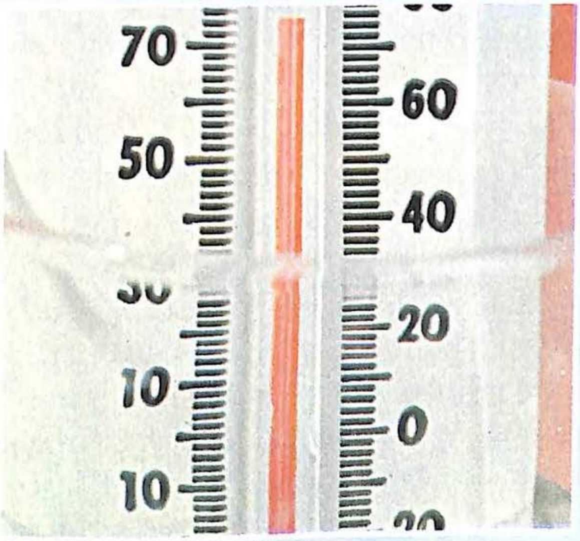

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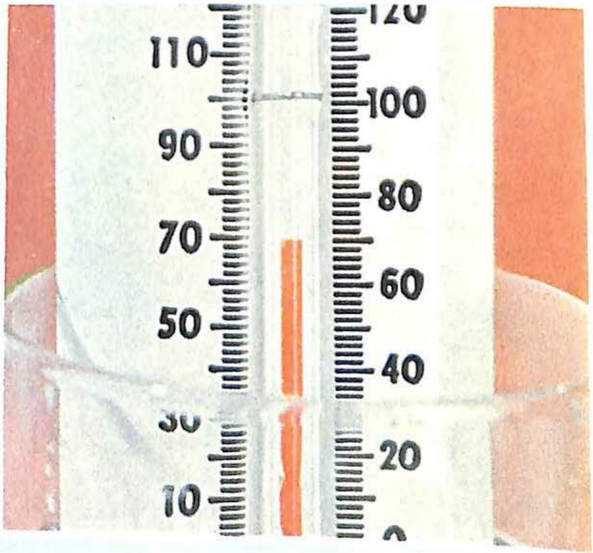

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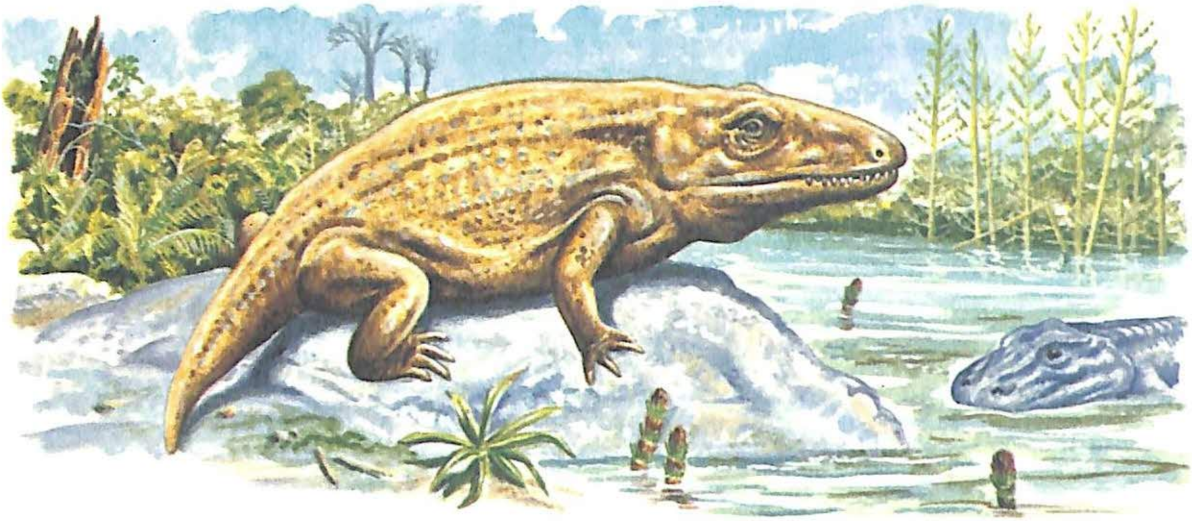


farther on land. *In time, somewhere on land, amphibians gave rise to the early reptiles.*

The first reptiles were strange creatures, to be sure. One may have looked like this, we believe. ■ These reptiles began to rule the land.

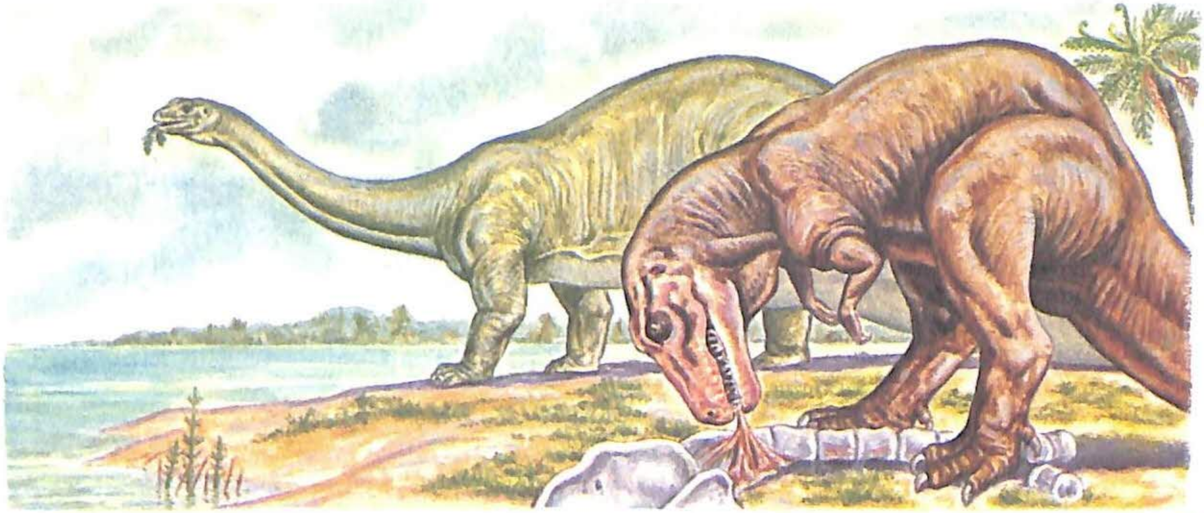
Reptiles are better fitted than amphibians to live on land. An amphibian, you may remember, has a moist skin through which it breathes. A reptile's skin, however, has scales which help keep it from drying out. A reptile breathes with lungs and does not have a moist skin for breathing.

■

A reptile, moreover, lays eggs with tough shells and lays them on land. The shells keep the young from drying out. An amphibian lays eggs that have no shells on them and lays them in water.

You already know something of the early reptiles, the dinosaurs. ● Think how huge and terrifying some of them were. Some were 18 feet tall! There were dinosaurs of many different kinds. Some reptiles were able to fly. They did not fly with feathered wings, however. They had a sheet of skin stretched over the arms and toes.

Some of these early reptiles left the land and lived in the water. These sea reptiles still breathed by means of lungs. When one came to the surface, it took a great gulp of air which lasted it for some time. ▲ These creatures



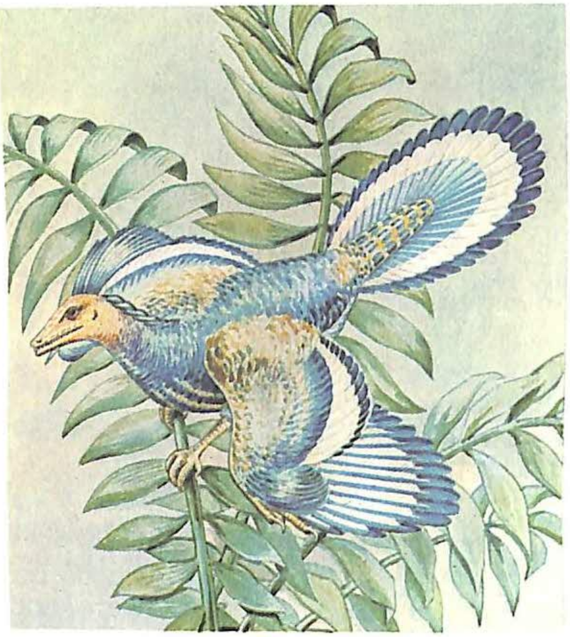
were strong and fast and must have ruled the early waters. However, most reptiles lived on land.

Scientists have called this ancient age, some 160 million years ago, the Age of Reptiles.

The Death of the Dinosaurs

The powerful dinosaurs ruled over all. They roamed the land. Some of them lived on plants. Some lived on meat and fought and killed each other for food. Even when they were not hungry, they fought as wild animals do.

All the time the land was becoming drier. Tree ferns became scarce, for they grew only where the land was wet and warm. Then the huge reptiles began to die out. In time, over millions of years, the dinosaurs disappeared.



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No one is sure why this happened. Perhaps the land became too dry. Perhaps the food gave out. Perhaps the dinosaurs fought so much that they killed each other off. Or perhaps their eggs were laid where they could be eaten by other animals. No one knows.

Some ancient reptiles didn't die out, however. Some of them must have been ancestors of reptiles living today. Our lizards, snakes, and other small reptiles are related to the king dinosaurs.

Then came a great event. *Toward the end of the Age of Reptiles, birds and mammals began to appear.*

The story in the sedimentary rocks gives us an idea of what the first **bird** we know of looked like. ■ It had scales like a reptile and few feathers! It was very different from the birds of today.

Along with the first bird came the animals that were to rule the world, the ones you will read about next.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. A water environment is safer because the temperature changes
a. slowly b. quickly

2. The first land animals came from a kind of
a. insect b. fish

3. The earliest land animals were
a. reptiles b. amphibians

4. The amphibians gave rise to the
a. birds b. reptiles

5. The reptiles gave rise to the birds and the
a. mammals b. trilobites

B. Write a paragraph or two on this topic: "The First Land Animals."

USING WHAT YOU KNOW

1. Why can't a salamander or frog stand drying out? (*A hint:* Fishes take in oxygen that is dissolved in water. The skin of a salamander is moist.)

2. The eggs of fishes and amphibians are laid in water. Those of reptiles are laid on land.

Why can't the eggs of fishes and salamanders survive on land? Why do the eggs of reptiles have a better chance of surviving?

3. Why do the eggs of birds have a better chance of hatching than do the eggs of reptiles?

ON YOUR OWN

1. Do an investigation into the adaptations of birds.
   a. Get a lamb bone or a beef bone. Compare it with a chicken or turkey bone. Break both bones in half. How are *hollow* bones important to birds?
   b. Get a tail or wing feather, and study it with a lens. What is the importance of the *hollow* quill? What is the importance of the curve of the feather?

2. *Feathers and Flight,* by Clarence J. Hylander, published by Macmillan, New York, 1959. To learn more about the meaning of adaptation, look into this book. It explains the principles of bird flight and the adaptation of wings of birds.

3. *Discovering Dinosaurs,* by Glenn O. Blough, published by McGraw-Hill, New York, 1960. Here is a good introduction to dinosaurs and how they lived.

4. *Before and After Dinosaurs,* by Lois and Louis Darling, published by Morrow, New York, 1959. In addition to information on the Age of Reptiles, this book deals with the changes in amphibians and mammals through the ages.

■

5. Up to Now

What did the first **mammals** look like? We don't know exactly. However, we do have an idea, based on fossil evidence discovered in the rocks.

The early mammals had coats of fur or hair, as all mammals do. The evidence suggests that they were small animals.■ They were not very different from the shrews we have today. Some early mammals may have laid eggs, like the duckbilled platypus.● The duckbill lives in Australia. It lays eggs that have shells around them. When duckbill eggs were first discovered, people thought they might be the eggs of a reptile. They look much like the eggs of a turtle.

After the young of the duckbill hatch out of their eggs, they are fed with a strange milk made by the mother. Most people would not recognize it as milk. It is more like very thin white of egg.

Is the duckbill part reptile? It would be better to say that it is a mammal which hasn't changed much over millions of years.

Protecting the Young

The eggs of the reptiles of long ago hatched outside the reptile's body, as do the eggs of reptiles living now. Often the eggs were eaten by other animals. Sometimes the eggs dried up in the heat or froze in the cold. One way or another, the eggs of reptiles were exposed to many dangers. But the eggs of mammals were protected inside the mother's body. This is one reason why mammals came to rule the land.

The young of mammals are carried inside the mother, so they are well protected. The young are fed inside the mother's body. The young of many mammals are born almost ready to

●

take care of themselves, except for getting food. A young horse can stand up and walk about in only a few minutes after birth. So can the young of cattle.

The young of rats, mice, and rabbits are born naked and blind. It takes almost 2 weeks for young rats to grow fur and be able to scamper about.

There are some mammals today whose young are born not fully developed. Even if you haven't visited Australia, you know of the kangaroo and the koala bear. Each is a mammal which carries its young in a pouch. This picture shows young kangaroos carried in the pouch of their mother. ▲ The young of the kangaroo are born blind and without fur. Quickly they climb into the mother's pouch. There they are kept warm, and there they are fed with the mother's milk. After a few months in the pouch, they begin to look like kangaroos. The young kangaroos climb out of the mother's pouch to hop about. Whenever there is danger they scamper back into the pouch. The mother protects them in this way until they can care for themselves.

The young of mammals are fed and taken care of by the mother for a longer time than are the young of any other kind of living thing. You can see that the young of mammals have a better chance of growing up than the young of reptiles.

▲

The young of birds and mammals are protected until they can take care of themselves. *Birds build nests and feed their young.* Young mammals develop within the mother and are fed until they can feed themselves and hide from their enemies. The young of most fishes, amphibians, and reptiles are at the mercy of their enemies. Fishes eat young fish just hatched. Frog tadpoles are food for other animals. Young snakes are eaten by birds.

The young of mammals and birds are protected, kept warm, and fed. This is an adaptation to the environment which has made mammals and birds successful. There is an adaptation which helps the adult bird and mammal survive, too. The investigation on the next page will help you understand this adaptation.

AN INVESTIGATION into a Steady Temperature

Needed: a clinical thermometer (oral), an ordinary thermometer, and you

Take the temperature of your classroom with the ordinary thermometer. As you do so, take your own temperature in the classroom with the clinical thermometer. Be sure to sterilize the clinical thermometer before putting it in your mouth by dipping it in alcohol and then washing it off under running *cold* water. Place the bulb of the thermometer under your tongue, and keep it in the mouth for about 1 minute. Be careful not to break the thermometer!

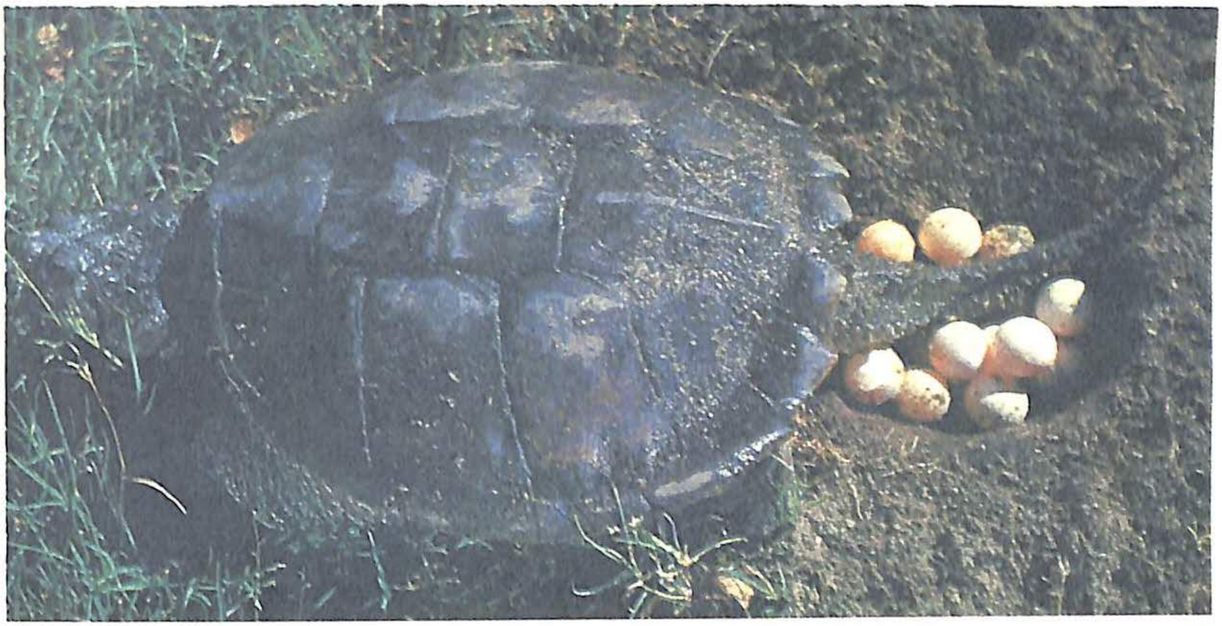
Next, take the temperature out of doors with the ordinary thermometer. At the same time take your own temperature out of doors.

Take these temperature readings once a day for a week and record them. A table like the one below may help you to keep them in order. You will be able to see how your temperature was affected by the temperature of the environment.

A student in a northern state recorded these temperatures during a week in January on one trial.

What do you conclude from these observations, and your own, about body temperature? What is one of man's most important adaptations to his environment?

	OUT–OF–DOORS		INDOORS	
Day	Air Temperature	Body Temperature	Air Temperature	Body Temperature
1	39° F	98.5° F	69° F	98.5° F
2	29° F	98.4° F	75° F	98.4° F
3	29° F	98.6° F	72° F	98.6° F
4	26° F	98.8° F	68° F	98.8° F
5	32° F	98.3° F	65° F	98.3° F



Changes in Living Things

Ancient living things that lived in the water changed into forms that could live on land. Cold-blooded living things gave rise to warm-blooded living things that could keep a steady temperature. Living things that laid their eggs outside the body gave rise to living things whose eggs developed inside the body. ■ All these changes took place.

Organisms which were adapted to life in water gave rise to organisms which were adapted for life on land. Slowly, over millions of years, changes in structure took place in the fish. Some of these changes were in the fins. The fins of certain fishes changed to a kind of flipper foot. Those fishes that didn't develop the flipper foot stayed in the seas. Those fishes that did develop it could try the land.

Of course these early land animals developed other adaptations, such as lungs. How do these changes come about? The changes first take place in the chromosomes. You may recall that chromosomes are the bodies in the cells responsible for the characteristics we inherit. *The changes in the chromosomes came before the changes in structure of living things.* Before the toes of the horse became a hoof, changes took place in the chromosomes within the horse. After millions of years horses with hooves took the place of horses with toes. The changes did not happen suddenly. They took place over millions of years.

Once upon a time (but this is no fairy tale) dawn horses roamed over our plains. Now there are no dawn horses. Early camels once plodded across what is now Wyoming. Now

■

only their fossils remain. The huge mammoths, long-haired and long-tusked, once fought battles in the early lands near Nebraska. ■ Early man hunted the mammoth. Now no mammoths are alive.

As the dinosaurs had vanished from the Earth, so those great mammals vanished, even the strongest and fiercest of them. However, the mammals we know today—dogs, cats, tigers, horses, camels, elephants, and all the rest—have come from those vanished mammals of long ago.

When modern man came on the scene, the animals and plants of the world were much as you see them now. Dog and horse, cat and mouse, camel and elephant, giraffe and gorilla looked much as they do now.

Plants, too, had taken the forms we see today. The giant tree ferns had disappeared. Mosses and ferns looked much like those we have today. So did grasses and trees. Modern plants and animals had taken over all parts of the Earth.

When man came on the scene, he found a great variety of living things. He found other things as well. He found coal and oil. Iron, copper, silver, and gold were in the Earth's crust. Great forests were his, and rich soil. The rivers, lakes, and seas teemed with life. Man found great riches around him.

BEFORE YOU GO ON

A. Study these statements and choose the correct responses. They will help you fix in mind the concepts of this section.

1. The young of the duckbill hatch out of

a. eggs   b. a pouch

2. One adaptation which made mammals more successful than reptiles was that mammal young were protected

a. inside the mother   b. inside eggs

3. Another adaptation which fitted mammals for success on land was their

a. unsteady temperature   b. steady temperature

4. Changes in the structure of living things came about

a. after changes in their chromosomes
b. before changes in their chromosomes

5. Early man once hunted

a. dinosaurs   b. mammoths

B. Write a paragraph or two on this topic: "Why Mammals Are Successful Animals."

USING WHAT YOU KNOW

1. Is there any place in the world where mammals cannot be found?

2. Compare the adaptations of mammals with the adaptations of reptiles.

a. Why can mammals live in very cold regions while reptiles generally cannot?
b. Why do the eggs of mammals have a greater chance of survival than the eggs of reptiles?

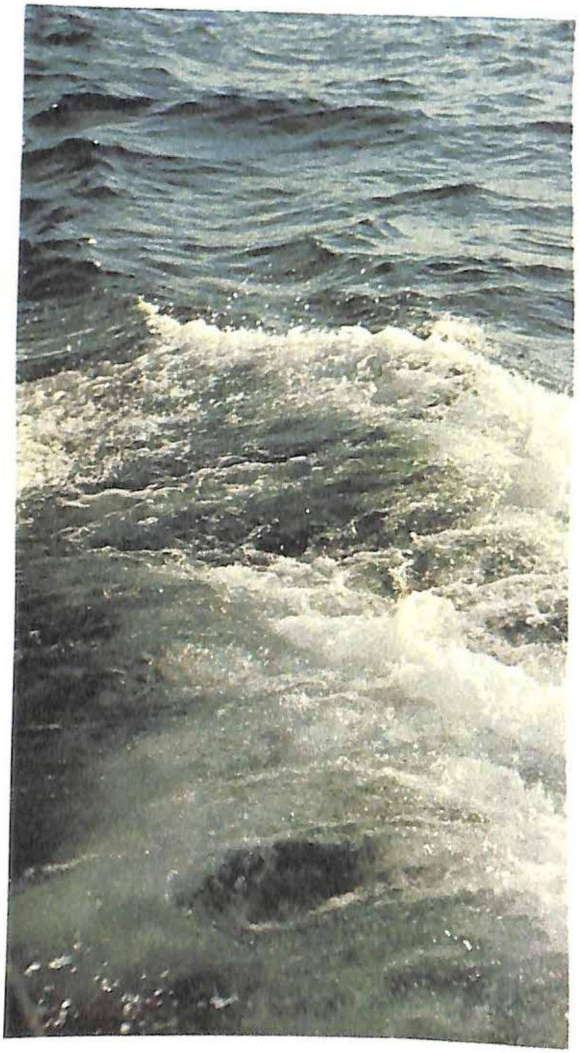
ON YOUR OWN

1. With the permission of your teacher, prepare two bulletin boards on

a. the mammals of Australia
b. the mammals of Africa

Different committees of students might study different mammals. For instance, some students might collect information and pictures on the pouched mammals or on the egg-laying mammals. Other students might study mammals like the chimpanzee and the gorilla.

2. For your reading: *Exploring the Animal Kingdom*, by Millicent Selsam, published by Doubleday, New York, 1957. This book not only tells about different kinds of animals but also tells how mammals have changed during the history of the Earth.



6. The Main Concept: The Story in the Earth

We have added to our story of the changing Earth.

Many scientists think that there was a time when the Earth was just a ball of hot matter revolving around the Sun. As the ball cooled, the mixture of gases that surrounded it cooled, too. The water vapor in that atmosphere cooled and began to rain down. It was a long rain, thousands of years long, scientists think. From it came the early oceans. ■

Volcano after volcano burst out of the young Earth, as melted rock came bubbling to the surface. The crust slowly cooled. The rock began to weather and break down, cracked by heat and cold. Erosion began. Weathered rock was carried down into the ocean, where the first sedimentary rocks began to form.

There was no life on Earth.

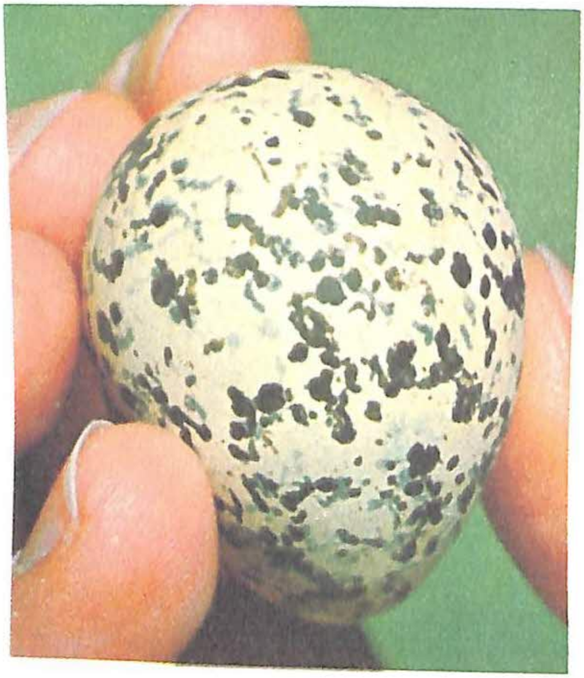
Slowly, year after year, the sediment streamed into the ocean to form rock. The rock layers became deeper and deeper, heavier and heavier, pressing on the material beneath them. In places this pressure heaved up the Earth's crust. Slowly these mountains were worn down.

These things are still going on. Right now, sedimentary layers are pressing down. Right now, as this pressure slowly grows, the Earth's crust is lifting in places. Earthquakes and volcanoes show that the Earth is still changing. Erosion is still cutting down mountains and building up new land. Since it is still a young planet, we think that these changes in the Earth will go on for a long time.

And now we know that *plants and animals are changing too.* We know it through the work of fossil-hunting scientists. They have found evidence to show what life was like on Earth as far back as 2 billion years ago.

The first plants in the seas and waters were simple flat-bodied plants. Then mosses and ferns covered the warm, moist land. Tree ferns grew in forests. Finally, our present flowering plants, grasses, shrubs, and trees came to be. Simpler plants, without roots, stems, or flowers, came first. Plants with different, more complex structures came later.

The single-celled animals were first in the early waters. Then the waters filled with simple invertebrates—sponges, jellyfish, worms, and starfish.



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The trilobites, very much like our crabs and lobsters, came along next. Then came the squid and clams. All these changes took many millions of years.

From the invertebrates came the first vertebrates, the fishes. Then one kind of fish took a great step. It came up on land. From this fishlike ancestor came the great amphibians. From the amphibians came the great king reptiles. These changes, too, took millions upon millions of years.

The story of changes in living things is also the story of new adaptations in living things. The fishlike ancestor that came out on land developed *new structures which adapted it* to live on land. These changes in structure in living things came from changes in the chromosomes.

These adaptations for life on land appeared: eggs with a hard cover. ■ Lungs. Feathers. Fur. A steady body temperature. These adaptations meant that the living things were better fitted to live on land.

The first true land animals were the reptiles. The amphibians, after all, laid their eggs in water. The amphibians lived part of their lives in water. But the reptiles, especially the dinosaurs, were true land animals. The reptiles ruled for a long time. They were in the air, on the land, and in the seas. From them, in turn, came birds and mammals. The evidence is clear. *Living things now on Earth developed from earlier living things.*

Today the mammals rule the world. The mammals, of all the vertebrates, have taken hold over the land. However, the insects have taken hold too, among the invertebrates. The insects are challenging the mammals' rule of the land.

When man came upon the scene, he found all this. By using his brain, he has become master of the Earth. It is true that man doesn't always use his mastery wisely. It is true that the insects are giving man a great battle. Still, man rules this planet, this changing planet with its changing life.

Today man looks beyond the Earth. He is beginning to venture out into space. He is looking towards an investigation of other planets.

Fixing the Main Concepts

TESTING YOURSELF

A. Test your understanding of important concepts in this unit by doing these problems.

1. Put these living things in order of their appearance on Earth.
   - a. spiny-skinned animals (invertebrates)
   - b. reptiles
   - c. mammals
   - d. fishes

2. How are mammals better adapted to live on land than amphibians?

3. Igneous rock was formed with great heat. Would you expect to find many fossils in igneous rock? Why?

B. Test your understanding of the main concepts in this unit by using each of these key words and phrases in a sentence.

invertebrates
vertebrates
adaptation
fossil
sedimentary rock
reptiles
amphibians
fishes
birds
mammals

C. Test your knowledge with this quick check.

1. The group of animals that came earliest in time is the
   a. ostracoderms b. dinosaurs c. insects

2. The group of animals that came earliest in time is the
   - a. single-celled animals
   - b. back-boned animals
   - c. many-celled animals without backbones

3. The group that came latest in time is the
   a. birds b. amphibians c. fishes

ON YOUR OWN

Many different kinds of animals and plants have been formed in the $4\frac{1}{2}$ billion years the Earth has existed. There is a great *variety* in living things on Earth today.

Make a collection of one group of living things to show this great variety. You might make a collection, for example, of

shells leaves of trees insects

One such beautiful collection is shown in the photograph at the bottom of this page. ■

FOR YOUR READING

If the Earth's history, the development of living things, the adaptations of living things, and fossils interest you, then these books will interest you.

The Earth for Sam, by W. Maxwell Reed, published by Harcourt, Brace & World, New York, 1960. This book tells the

story of the changes in plants and animals over the ages. It deals with most of the important kinds of living things.

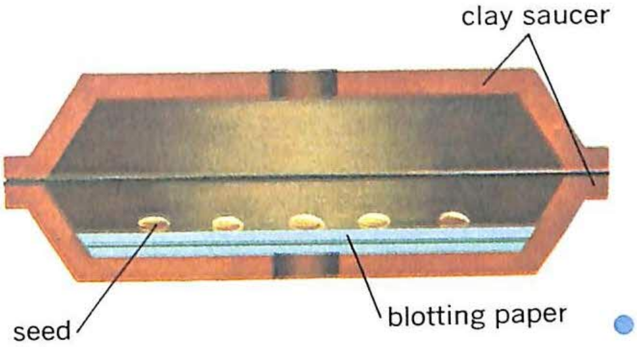
The First Book of Prehistoric Animals, by Alice Dickinson, published by Watts, New York, 1954. This book is an introduction to life on Earth before man's history began.

GOING FURTHER

An Investigation

You can see that some of the living things around you are related. For instance, all dogs seem to be related. They have much the same structure. Although there are differences between a spaniel and a bulldog, still, both are dogs.

All flowering plants are related. They have flowers and produce seeds. Can you separate the flowering plants into two groups? Try to do this by observing the way the seeds produce the young plants.



Take many different seeds: bean, squash, wheat, oat, radish, corn, pea, sunflower, grass, and as many others as you can get. Put one clay saucer on top of another to make the moist chamber shown in the diagram.● The two blotters on the bottom saucer should always be kept moist. Soak all the seeds overnight in water, then place them in the moist chamber. They will **germinate** (jûr′mə·nāt). That is, they will produce young plants.

Observe the way seeds of flowering plants produce young plants. Can you separate them into two related groups?

A New View of Change

We know that the Earth rotates on its axis. We know that the Earth revolves in orbit around the Sun. ■ We've become accustomed to the fact that our Earth is always on the move, in space. We know too that our Sun is but one star among millions in our galaxy—and that this galaxy is moving in space.

We know, then, that everything moves in space. No planet, no star, stays in one place. Everything changes.

Yet these changes do not frighten us, for we can predict them. We can predict where the Earth will be in its orbit at any moment. (How else could we hurl men into space and have them come back to Earth safely?) These changes seem to be going on in an orderly way. That gives us some confidence.

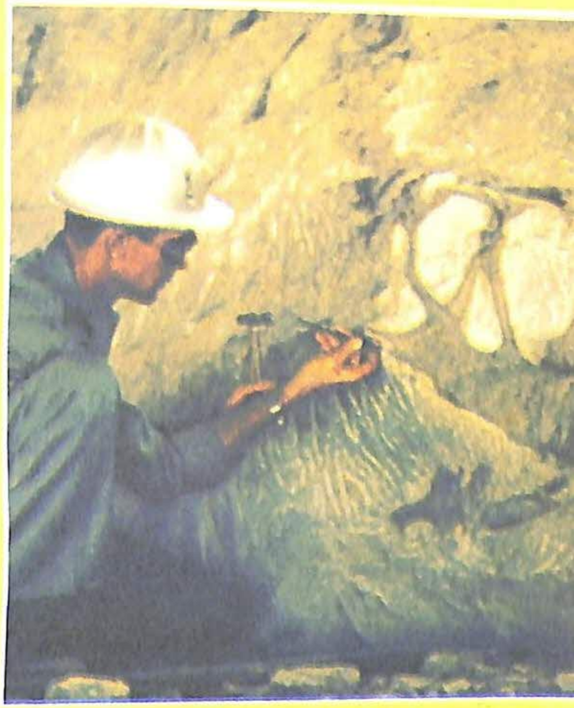
We see change going on elsewhere, too. Our Sun is not just a hot ball giving off light and heat. From its spectrum we have discovered that the Sun is almost all hydrogen and helium. Stranger still, the hydrogen is being changed into helium—and as this happens some of this matter is changed into energy. From this change comes the Sun's light and heat.

■

The Sun is constantly changing then. Its matter is being changed into energy. It is light energy coming from the Sun that makes life possible on Earth. And scientists believe that the changing of matter into energy goes on in all the stars whose light we see.

The whole universe is constantly changing.

Why should we be surprised at this? We live, after all, on a planet that is constantly changing. Here on Earth the day gives place to night, winter to spring, fair weather to foul weather. Mountains rise up, quickly like volcanoes, or slowly, like the Rockies, over millions of years. The mountains change again; water, wind, ice, and heat slowly break them down. The mountains are weathered and eroded, and the sediment which flows from them lays down on the sea bottom another story of change.



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A Story of Change in the Rocks

No one has ever seen a live dinosaur. ●

Yet we know dinosaurs lived. They lived in an environment no longer found on the Earth. Why did they disappear? The environment changed —and the dinosaurs did not change fast enough to match the changes in the environment. So no man ever saw live dinosaurs: they had left the Earth long before man arrived. Yet the story of the dinosaurs is clear, in the sedimentary rocks. In the sedimentary rocks a great story of change unfolds.

Some 2 billion years ago, single-celled animals lived on the Earth. Over millions of years these single-celled animals changed, and gave rise to many-celled animals. These many-celled animals were without backbones; they were invertebrates. They swarmed in the oceans—spiny-skinned animals, shelled animals, jellyfishes, sponges, and others. There were no animals on land.

In time the invertebrates gave rise to vertebrates, animals with backbones. These were the fishes, the most successful water-living vertebrates. As time went on, the fishes changed too. And the time came when the fishes had changed enough to produce an animal that came up on land. This was a great adventure.

■

From these animals that left the sea came the huge early amphibians. (All that is left now of these great amphibians are frogs, toads, and salamanders. ■) The huge amphibians gave rise to the reptiles; the reptiles, dinosaurs among them, ruled the Earth for millions of years. All that is left today of those great reptiles are our snakes, turtles, lizards, alligators, and crocodiles.

In time some reptiles gave rise—so we read the story in the rocks—to the birds and mammals. In time the mammals ruled the world, as they do now.

We Live with Change

We study the changing universe—its stars, its planets, its space. We study the changing Earth—its seasons, its weather, its moving surface. We study living things, and find change there too—from single-celled animals to many-celled animals, from invertebrates to vertebrates.

We see change everywhere. So we have built two great concepts which help us to understand this world in which we live.

The Earth and its living things are always changing.

The universe and its bodies are always changing.

We see change everywhere. But we find order in the changes. When these changes are regular and orderly, we can predict them. We can predict changes on the Earth. We are getting to know how to predict changes in living things. We're beginning to understand the orderly changes in the universe. ●

We know much. Yet what we know is very little compared to what we need to know. (And as we learn more, what we think we know changes!) Indeed, as we study changes in the world of matter and energy and living things, science changes our lives. For we use the knowledge that we gain by science to change the world we live in. As we change the world, we change the way we live.

●

ON YOUR OWN

PROBING THE EARTH'S CRUST

This planet Earth is an interesting place, you know. Yet many people go along without enjoying Earth's ever-changing forms of living things, of paintings, of music, or of rocks and minerals. The aim of this part of this book is to acquaint you with some of the beautiful and useful rocks and minerals of the Earth and to help you enjoy them.

All Around You

There are rocks and minerals all around you. Wherever erosion takes place, rocks come into view. Man exposes rocks and minerals whenever he digs and builds. Wherever there are new roads, new houses, new bridges, wherever the ground has been broken open, look for rocks that have been brought into view.

Don't overlook the buildings around you and the paving under your feet! They may reveal rocks and minerals and the action of weathering and erosion as well.

Wherever you go for rocks, however, take care to ask permission. The owner of a property may be glad to have you look around, but he wants to know what you are doing. So do your parents, of course, and your teacher.

There are more than one hundred kinds of rocks, and about fifteen hundred kinds of minerals. Where to begin? We suggest that you begin by collecting rocks. As you study them, you will begin to learn about minerals. A collection can be for study as well as for enjoyment. Collecting takes you out of doors. It is healthy. It brings new friends as you swap specimens. Collecting brings new knowledge, and it may even bring you a career. It may bring a career in geology, the science of the planet Earth and its history; or in mineralogy, the study of the Earth's minerals; or in petrology, the study of rocks. Mineralogy and petrology are both a part of geology.

How to Collect

What will you need for collecting rocks? Here are some items you might use.

1. A knapsack, for carrying rock specimens and equipment.
2. A geologist's pick, for making small specimens out of big ones.
3. A notebook and pencil, for making a record of the specimens.
4. A hand lens, for examining rock features too small to see with the naked eye.
5. A pocketknife, for scratching and scraping rock.
6. Heavy gloves, for wearing when the pick and pocketknife are used.
7. Some old newspaper, for wrapping specimens.
8. A canteen, for drinking water.
9. A friend; never collect alone, if you can help it.

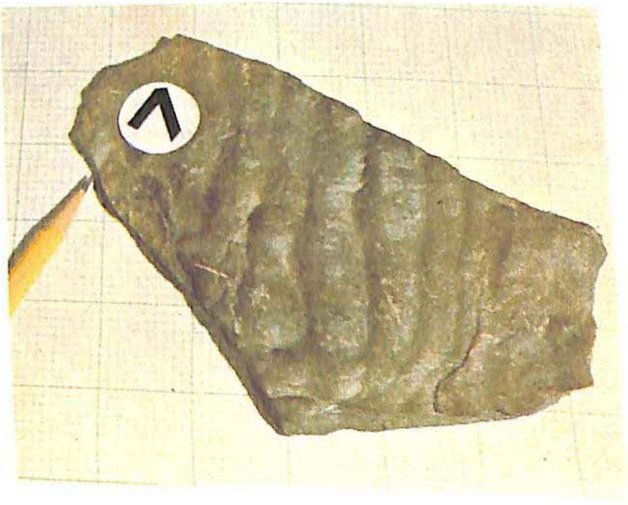
Collect a few specimens at a time, and hand-sized ones if possible. Wrap the specimen in newspaper and write a number on the paper. Then write the number of that specimen in your notebook. Note where the specimen was found. You may want to describe the location briefly (a railroad cutting, red soil, shiny pieces of red rock showing through soil). Put down the date as well. Then, at home or in the classroom, you can compare your specimens with the illustrations and descriptions that follow. When the specimen has been identified, label it. Paint a small circle of a quick-drying enamel (such as model airplane enamel) on the specimen. When the enamel has dried, you can write a number on it with black India ink.

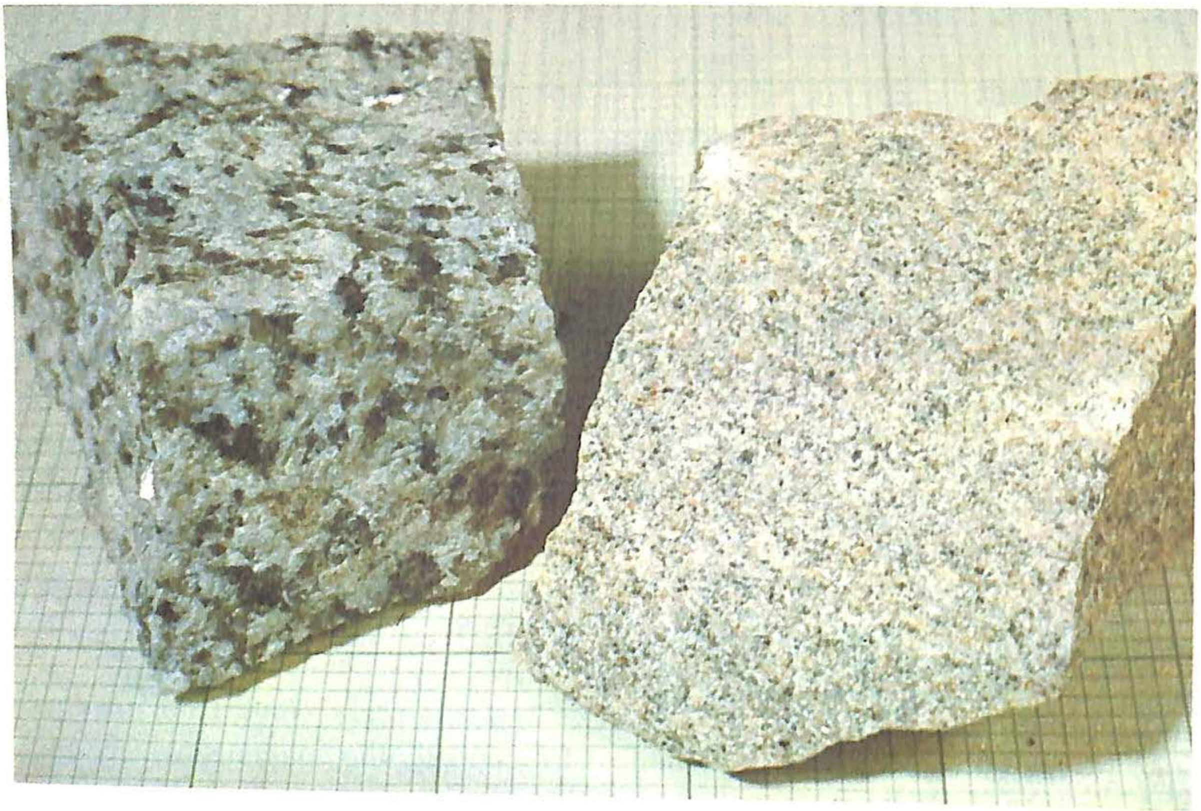
You will certainly want to consult other books for further study—for instance, books about the kinds of crystals in the rocks. Some useful books are listed and described on page 358.

IGNEOUS ROCKS

Igneous rocks come from magma. In general, the magmas which cool beneath the surface of the Earth form *intrusive* rock. Intrusive rock may be coarse-grained, because it cooled slowly deep below the Earth's crust. Magmas which reach the surface, through volcanoes for instance, form *extrusive* rock. Extrusive rocks cooled rapidly and have a fine-grained texture.

Here are some typical igneous rocks to look for, for your collection.





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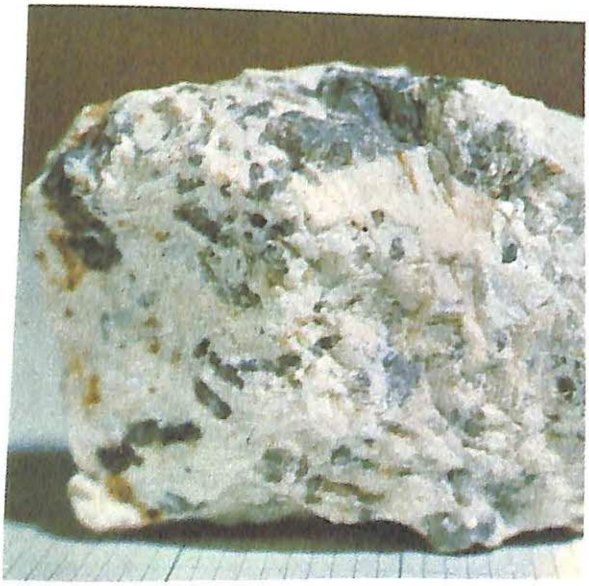
GRANITE

Granite (gran′it). Perhaps you already know granite when you see it. Most granite is light-colored. It has two main minerals in it—feldspar and quartz. There may be shiny bits of mica also. Granite has a "salt-and-pepper" pattern. ■ A great deal of the mineral called feldspar may make granite look red. (The large squares on the graph paper under the rocks have one-inch sides.)



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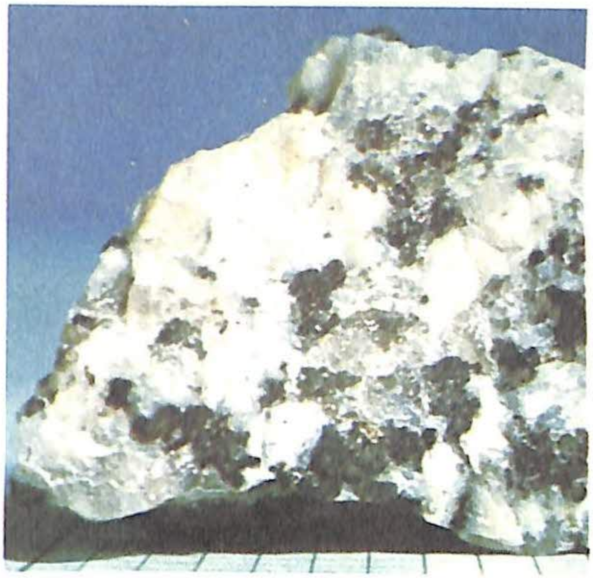
PEGMATITE

Pegmatite (peg′mə·tīt). A rock studded with crystals may be pegmatite. ● The crystals may be of mica, feldspar, or other minerals. Sometimes pegmatite is found having in it gems such as emeralds, sapphires, or rubies.



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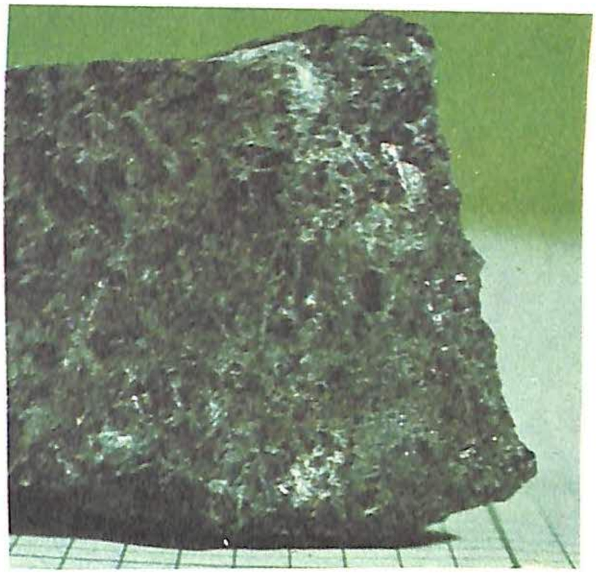

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GRANITE PORPHYRY

Granite porphyry (pôr′fə·rē). This is one of the easiest rocks to identify.▲ Huge crystals of feldspar, quartz, or mica seem to be embedded in granite.

GABBRO

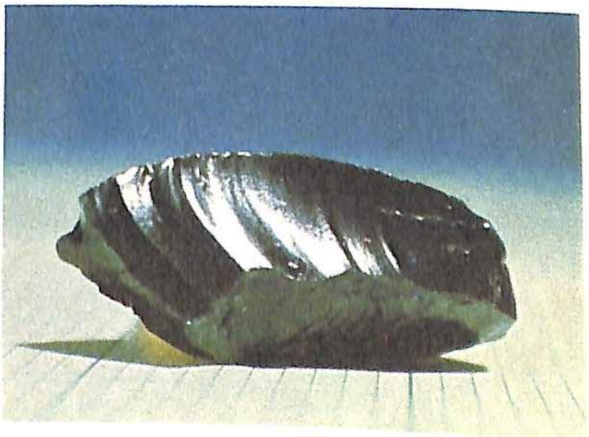
Gabbro (gab′rō). Most granites and pegmatites are light in color. Gabbro is dark, and much like granite in its salt-and-pepper appearance.◆ Crystals are deeply mixed in it. This makes gabbro a tough, durable rock. It is sometimes used for building but may show a rusty stain as it weathers.

Granite, pegmatite, porphyry-type rocks, and gabbros are mostly intrusive rocks. They are formed deep in the Earth's crust. Here now are some extrusive rocks formed on the surface of the crust.

OBSIDIAN

Obsidian (əb·sid′ē·ən). This rock is sometimes called natural glass.★ Indians made knives and arrowheads from it. Obsidian is formed when lava is cooled quickly. Although it is a dark rock, as you see, light can be seen through a thin piece of obsidian.

★



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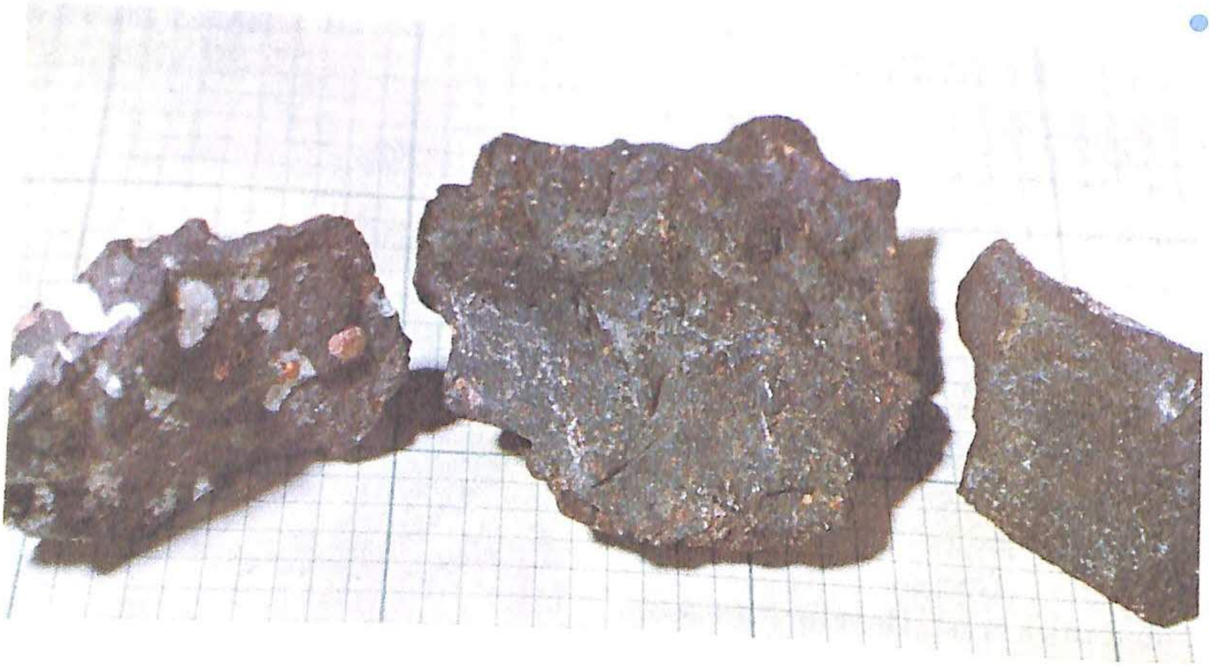
PUMICE

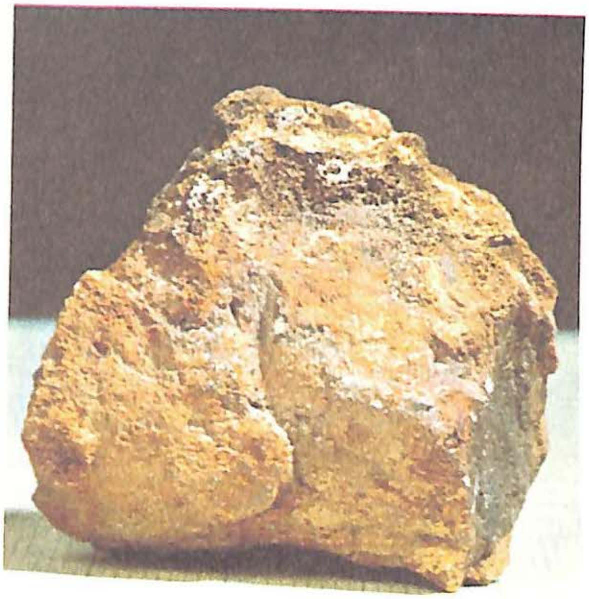
Pumice (pum′is). When gases bubble through hot lava, pumice may be formed. ■ This rock is so light that it floats in water.

BASALT

Basalt (bə·sôlt′). You might not take basalt for a kind of lava—but it is. ● Basalt is so fine-grained that its minerals are not clearly visible. Some basalts are almost green while others are quite black. In humid areas the iron in basalt rusts or oxidizes, and the basalt surface becomes rusty brown. Holes in the pieces of basalt on the left have become filled with minerals. Here is basalt with amethyst crystals embedded in one end. ▲ Amethyst is quartz, colored by impurities.

●





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SCORIA

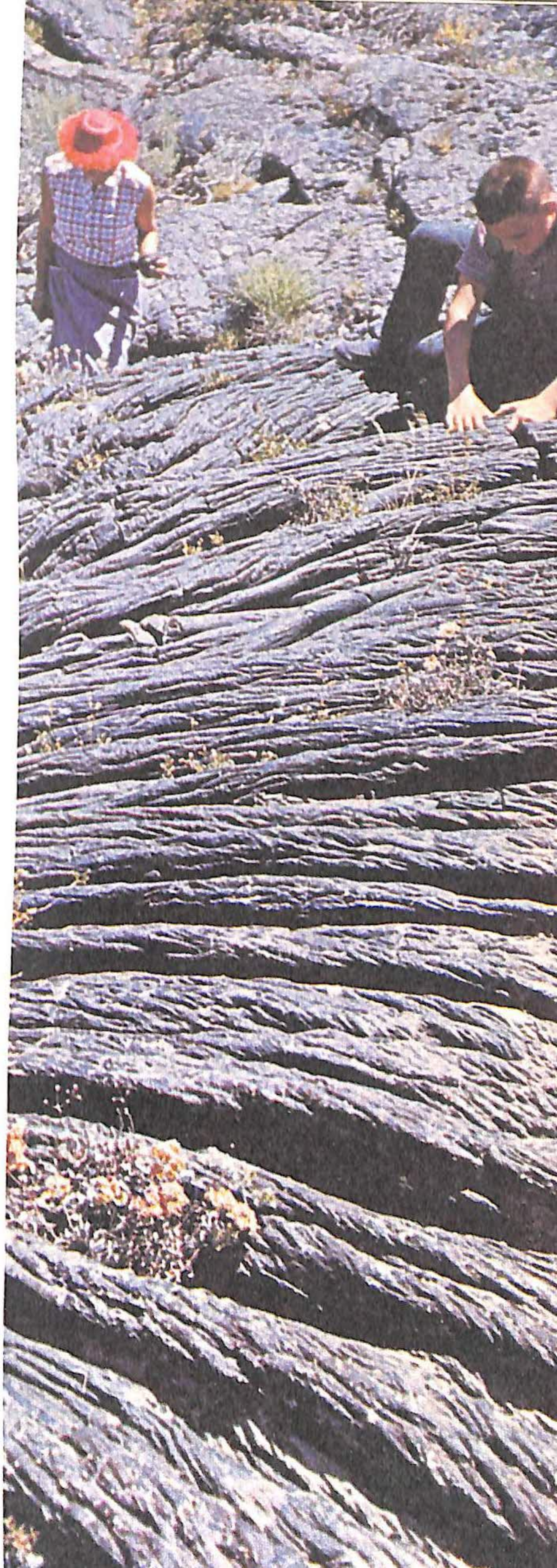
Scoria (skȯr′ē·ə). Basalts are usually very dense, fine-grained rocks. Basalt near the surface of a lava flow may have gas in it. The basalt rock may then become a porous rock, called scoria. ◆ As the gas escapes, the holes may become filled with minerals, such as amethyst and agate.

★

PAHOEHOE

Pahoehoe (pə·hōē′hōē′). This is a name the Hawaiians use for one kind of lava. ★ As the lava cools, it forms a smooth, ropy surface. The lava flows seem to be rivers of black, purple rock.

Another kind of lava with a Hawaiian name is aa (ä′ä′). Aa lava has a rough and jagged surface.



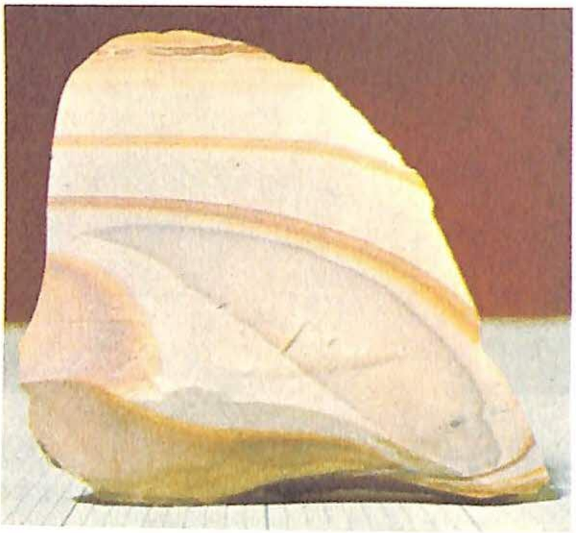
SEDIMENTARY ROCKS

Erosion acts on rock. Currents of all sorts—water, wind, ice—move bits of rock over the surface of the Earth to form sediment. Gravity pulls sediment downward. Slowly the sediment forms sedimentary rock.

Most sedimentary rocks are found in layers that were formed over millions of years. Many sedimentary rocks contain fossils. Sedimentary rocks form nearly three-quarters of the Earth's exposed rock surface. Here are a few common types.

SANDSTONE

Sandstone (sand′stōn′). Water, wind, and ice act on rock to free grains of quartz. These grains of quartz may pile up and be cemented together by particles of lime, or by iron oxide or silicates. When the grains are cemented together they make a sandstone.■ Sandstone may be coarse- or fine-grained. Many sandstones are formed in shallow seas or near shore. Layers have formed colored bands in this sandstone.●



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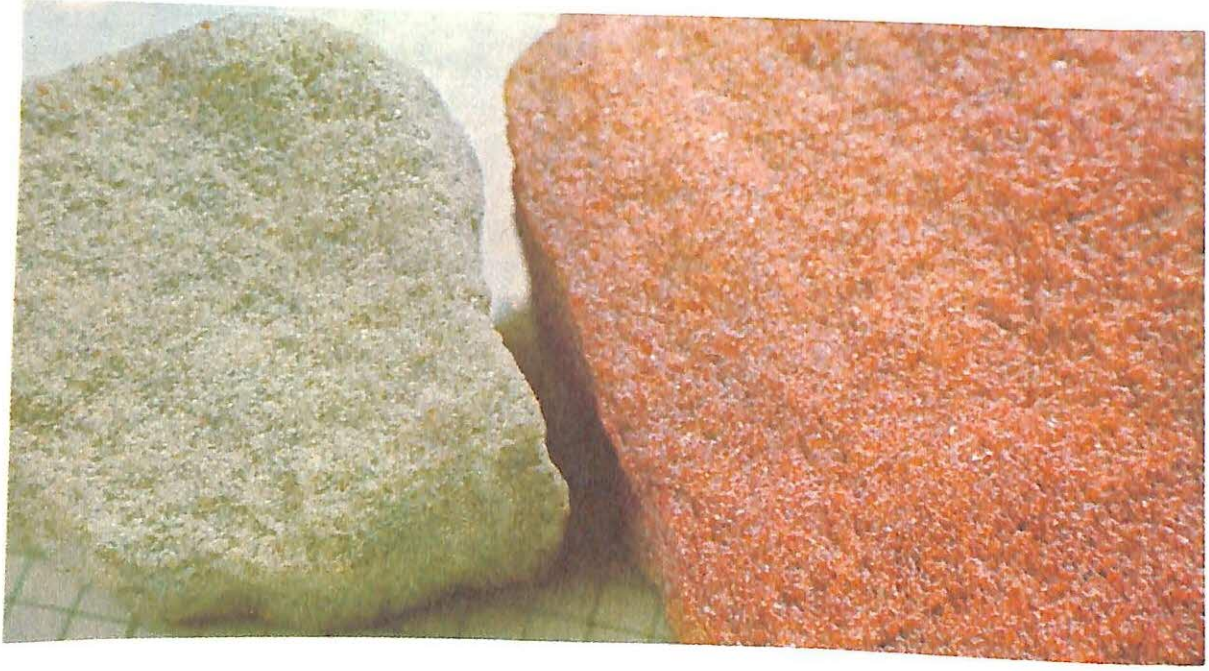

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SHALE

Shale (shāl). Formed mainly from clays of different colors, shales may be red, black, or gray. Since they are formed in quiet water and of fine particles, shales have very fine grains. ▲

Sometimes shale will be formed in light and dark layers, each pair of layers taking one year to form. The time during which this shale was formed may be determined by counting the layers.

LIMESTONE

Limestone (līm′stōn′). There are many limestones. ◆ They come in a great many different colors and different textures. Limestones are made of the mineral called calcite (calcium carbonate). They are formed under many different conditions. A geologist may be able to tell the origin of a limestone from the texture.

Both animals and plants may help to make limestone. Coral is mainly limestone, made by tiny coral animals

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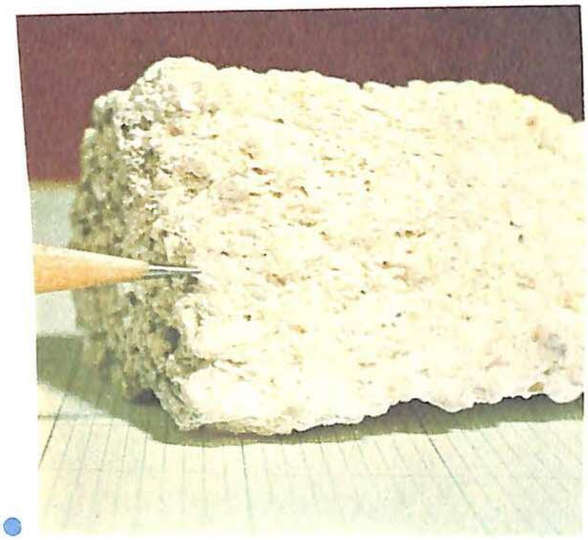

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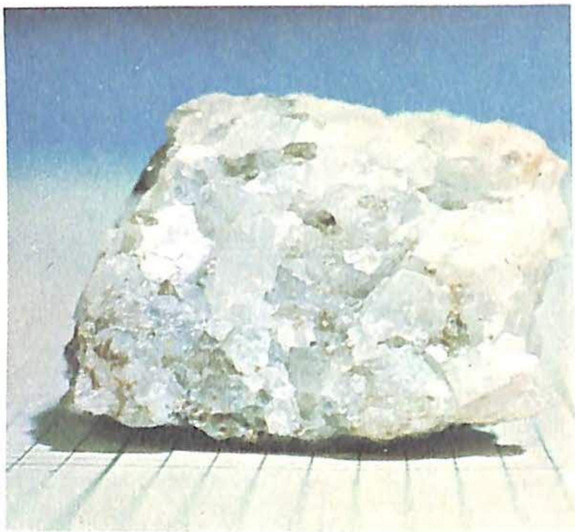
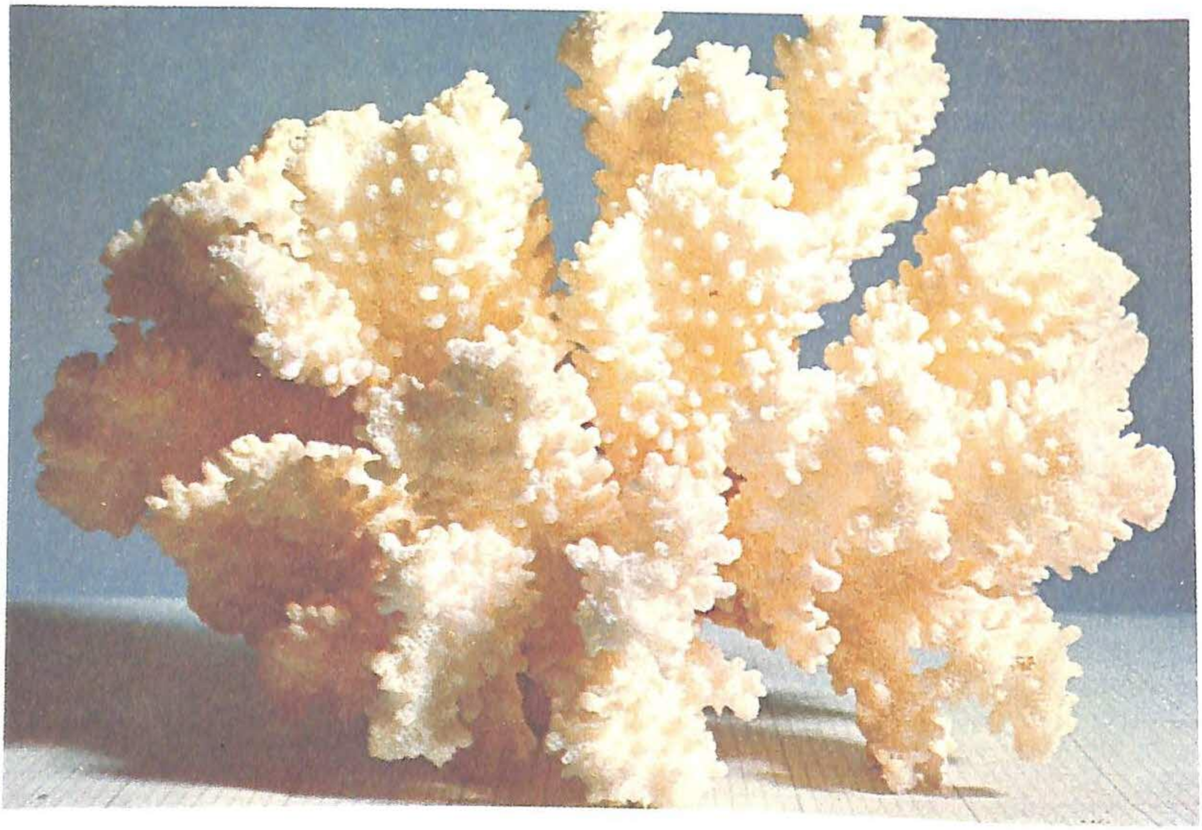


▲

below the surface of the warm sea water. ■ Some limestones are made of shells cemented together and are called coquina (kō·kē′nə). ●

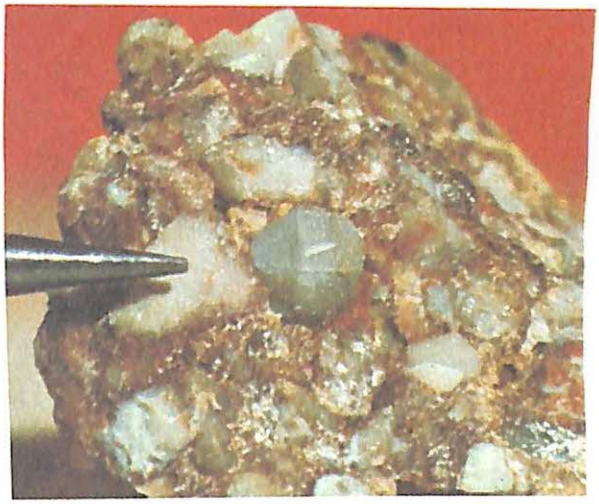
Crystalline limestone is formed as calcium carbonate crystallizes. It looks somewhat like marble, but marble is formed in a different way. ▲

■



CONGLOMERATE

Conglomerate (kən·glom′ər·it). This is the rock sometimes called puddingstone. Pebbles are embedded in sedimentary stone. ◆ Some conglomerate rocks have sharp and shiny stones cemented in sedimentary stone. Breccia (brech′ē·ə) is such a conglomerate rock.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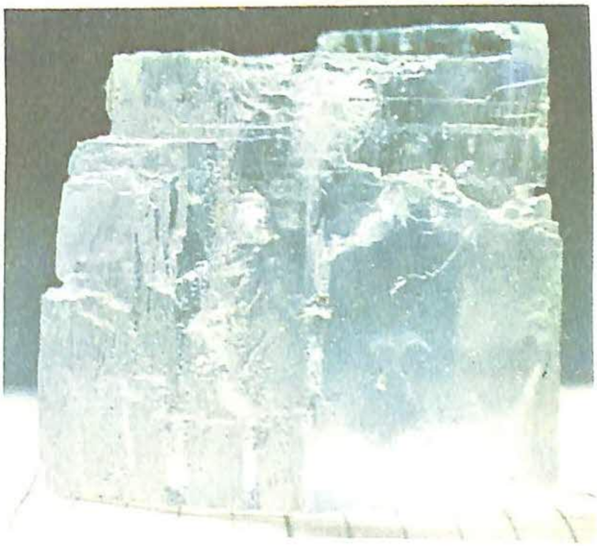
Chemically Formed Sedimentary Rocks

Sea water is a solution of many substances. Halite (hal′īt), made up of crystals of salt, is formed as sea water evaporates. ★

Diatomaceous earth is formed from the microscopic skeletons of certain plants called diatoms. ◆

Coal is considered to be a kind of sedimentary rock. ◎ Recall that when ancient trees fell they were sometimes covered by sediment. Over thousands of years the pressure of the sediment, and the heat caused by the pressure, produced coal.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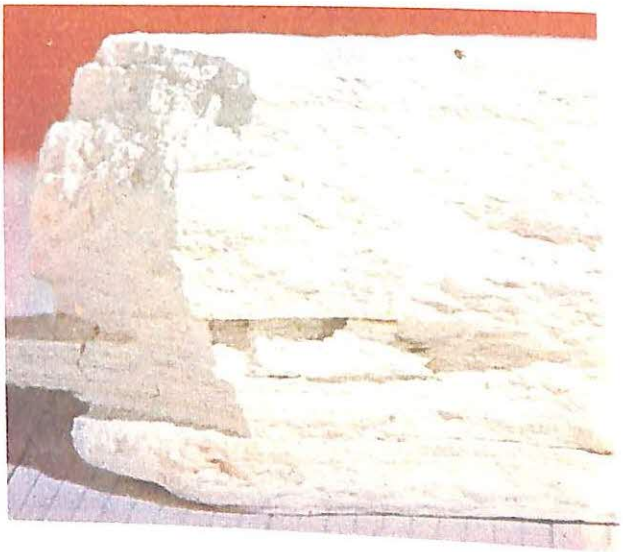
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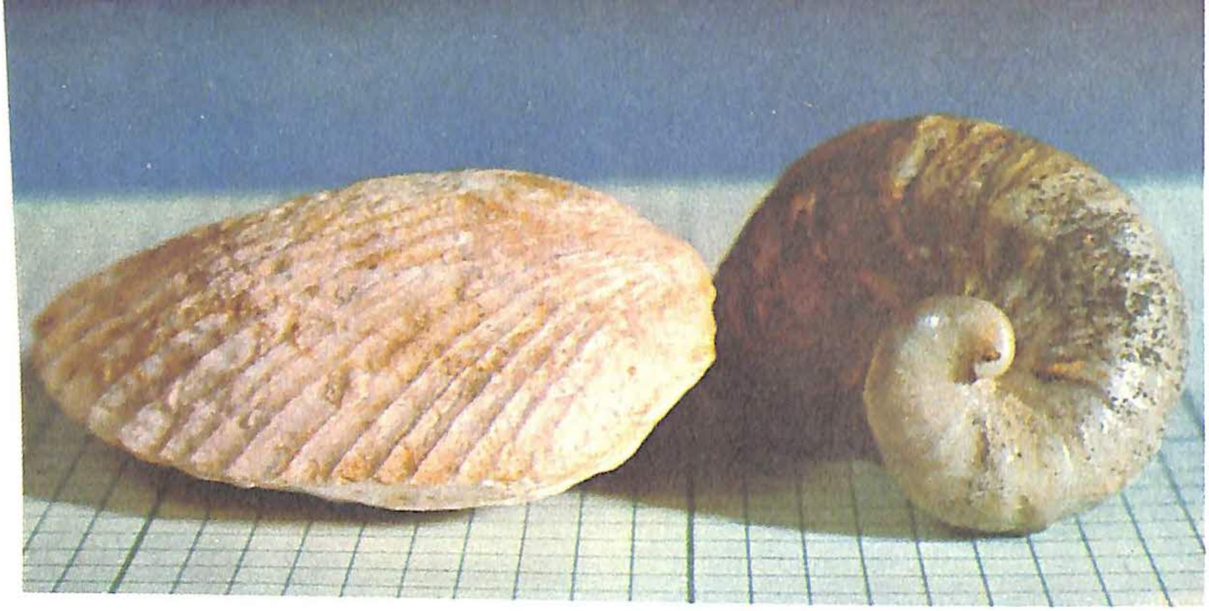

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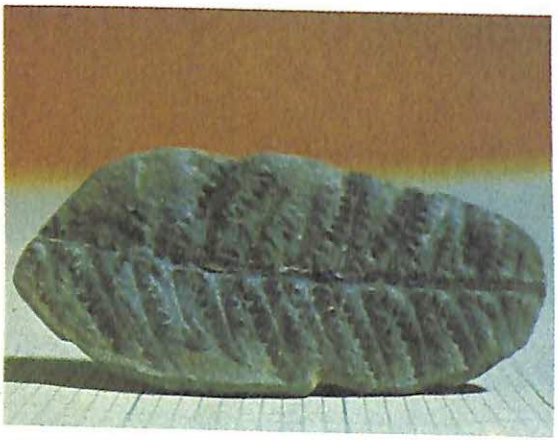

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Fossils

Fossils, the remains or prints of ancient plants and animals, are found most often in sedimentary rock. Best preserved are hard parts of the animal or plant, such as a shell or bone. These are fossil shells. ■

A leaf may decay, however, and yet leave a print. ● Or part of a plant may be replaced by minerals (producing petrified wood) in which one can sometimes see cells. ▲

METAMORPHIC ROCKS

Metamorphic rocks are simply rocks which have been changed. A rock may be changed by the weight of the rocks above it, or by heating, or by both squeezing and heating. It may be changed by minerals in water. All kinds of rock can be changed—igneous, sedimentary, even metamorphic rocks.

Heat and pressure may change rock in different ways. The structure of the rock may be changed. New crystals may be formed, among the minerals already present. New minerals may be formed within the rock. The texture of the rock may be changed.

SLATE

Slate is a metamorphic rock formed from shale. ◆ Shale, you may recall, is a sedimentary rock formed from clay. Like shale, slate can be split into sheets of rock. Have you ever seen a slate roof? The slate shingles are weather-proof and will last a long time, if they are properly fixed in place. They are cut from sheets of slate.

MARBLE

Marble is limestone that has metamorphosed (changed).★ It can be made to have a very smooth and highly polished surface. Marble is used by sculptors as well as by builders. It is often tinted by other substances, such as iron oxide.

SCHISTS

Schists (shists). These are metamorphic rocks which have a layered appearance. Some schists may have bits of other minerals in them. Mica schist contains flakes of mica. ◆

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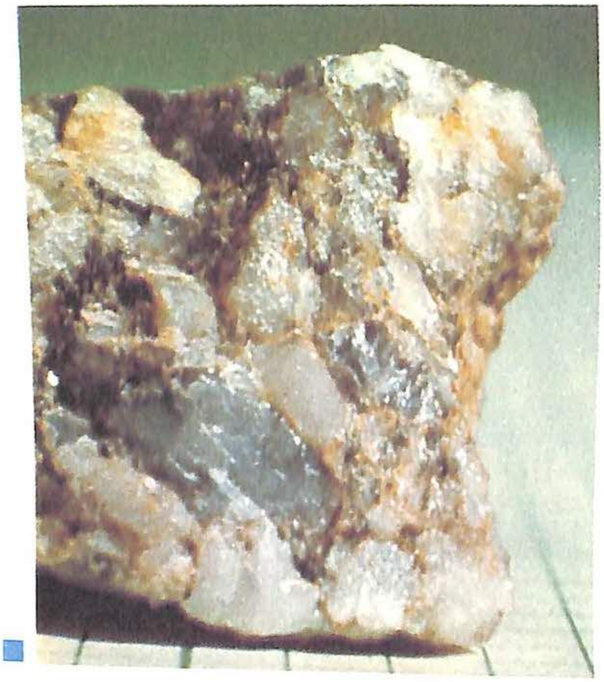
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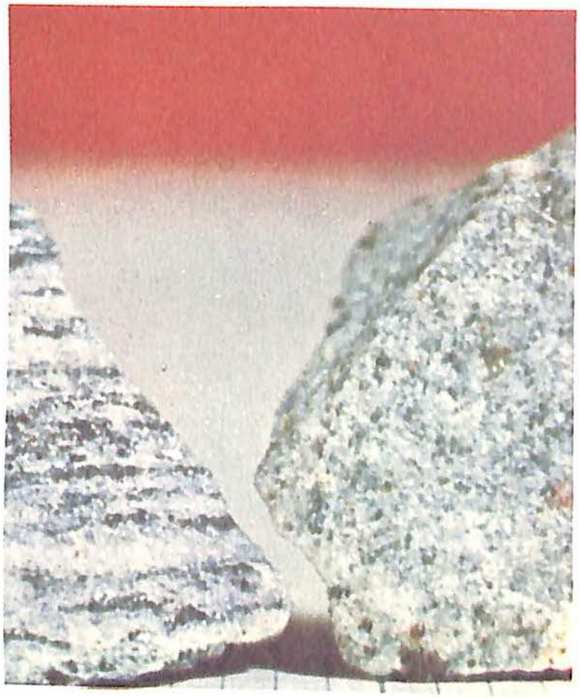
Quartz schist has crystals of quartz in it. ■

GNEISS

Gneiss (nīs) is a coarse-grained, banded rock. The rock seems to be striped. One form is probably metamorphosed granite. ● Some gneiss, for example, muscovite gneiss, has a black-and-white appearance.

The books given below help in identifying many rocks and describe simple tests that identify rocks.

1. *The True Book of Rocks and Minerals,* by Illa Podendorf, published by Childrens Press, Chicago, 1958. This little book is an introduction to the field of geology.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2. *My Hobby Is Collecting Rocks and Minerals,* by David E. Jensen, published by Childrens Press, Chicago, 1958. An advanced book on the tools needed and ways of collecting is useful when combined with the first book listed above.

3. *Rocks and Minerals,* by Herbert S. Zim and Paul R. Shaffer, published by Golden Press, New York, 1960. This is a well-illustrated book. In fact, the pictures take as much space as the text, if not more. An excellent book for identification. The descriptions of rocks and minerals use many technical terms, but the terms are defined. A very useful little book to carry on trips.

KEY CONCEPT WORDS: A BEGINNING VOCABULARY FOR SCIENCE

To record what they have learned from their investigations, scientists use words that have the same meaning to every other scientist; that is, scientists try to use words accurately. You are building up a vocabulary of key concept words of science during this year. You will, of course, want to use them properly. The first time a word is used with a special meaning for scientific communication, it is in boldface type in your textbook. In this vocabulary of key concept words, a page reference is given to refer to if you need more information or examples of the meaning than are given here. In other words, the definition given may need filling out. As you study science, the terms you use will take on fuller meaning. A few terms you probably know from earlier work in science do not have a page reference; you should already know how to use these words in their correct meaning. The index gives other page references.

PRONUNCIATION KEY

SYMBOL	KEY WORDS	SYMBOL	KEY WORDS	SYMBOL	KEY WORDS
a	*a*dd, m*a*p	o	*o*dd, h*o*t	u	*u*p, d*o*ne
ā	*a*ce, r*a*te	ō	*o*pen, s*o*	y	*y*et, *y*earn
ä	p*a*lm, f*a*ther	ô	*o*rder, j*aw*	zh	vi*s*ion, plea*s*ure
e	*e*nd, p*e*t	oi	*oi*l, b*oy*	ə	an unstressed vowel as in the words *a*bove, sick*e*n, clar*i*ty, mel*o*n, foc*u*s
ē	*e*ven, tr*ee*	o͞o	p*oo*l, f*oo*d		
i	*i*t, g*i*ve	o͝o	t*oo*k, f*u*ll		
ī	*i*ce, wr*i*te	th	*th*in, bo*th*		

action, a thrust or force acting in one direction that is equal to a thrust or force (reaction) acting in the opposite direction, 104

active (*volcano*), able to erupt or pour out lava, 26; (*element*) able to combine readily with other elements, 78

adapted, fitted to carry on life activities in a special environment, 221

ADP, the part of the ATP molecule that remains after it has broken down to yield energy in the cell energy process, 51

amphibian (am·fib′ē·ən), an organism, such as a frog or salamander, adapted by structure to spending part of its life in water and part of its life on land, 324

artery (är′tər·ē), a blood vessel that carries blood from the heart to the body, 211

atmosphere (at′məs·fir), the layers of gases around the Earth; the air, 44

atoms, the building blocks of elements and compounds, 27

ATP, a large molecule in a living cell, which, when it breaks down chemically, yields energy for the work of the cell, 151; *see also* **ADP**

auricle (ôr′i·kəl), a part of the heart that receives blood from the body, 212

axis (ak′sis), an imaginary line through the center of a body, such as the Earth, around which the body turns, 274

bacteria (bak·tir′ē·ə), single-celled plants, without chlorophyll, 168; some cause disease, 201

balanced force, a push or pull on an object that is equal to an opposite push or pull, 100

bathyscaph (bath′ə·skaf), a kind of submarine enabling man to explore with safety the depths of the ocean, 11

bird, a warmblooded animal that has feathers, lays hard-shelled eggs, and usually has the ability to fly, 328

blood cell. *See* **red blood cell, white blood cell**

blood vessel, any tubelike part in the circulatory system that carries blood, 210

bone cells, cells that make the substance of which bones are composed; bones give the body shape and support, 203

bone marrow (mar′ō), a tissue of soft cells and substances inside bones in which red blood cells are made, 217

bud, a new cell formed by growth from a parent organism or cell, as in yeast, 148; also a growing part (bud) of plants such as trees

cambium (kam′bē·əm), layer of living cells beneath the bark of a tree, 165

capillary (kap′ə·ler′ē), the smallest and narrowest of the blood vessels, 211

carbohydrate (kär′bō·hī′drāt), a compound of carbon, hydrogen, and oxygen, existing as a molecule; carbohydrates have two times as many hydrogen atoms as oxygen atoms in the structure of each molecule, 182

cartilage (kär′tə·lij), a substance made by cells that gives certain parts of the body support and flexibility, found especially between bones, 202

cell, the smallest living part of a living thing, 146

cell division, method by which a cell divides to produce two similar cells, 164

cell membrane, the outer boundary of the living cell of an animal, 153; the inner boundary of a plant cell, 160

cellulose (sel′yə·lōs), substance that makes up the walls of plant cells, 161

cell wall, the outer nonliving boundary of a plant cell, 160

cerebellum (ser′ə·bel′əm), the part of the brain that is the center for control of the movement of muscles, 218

cerebrum (ser′ə·brəm), the part of the brain which is the center of thinking, imagining, 218

chemical change, a recombination of atoms and molecules that results in a substance or substances with different properties; the result of a chemical reaction, 86

chemical reaction, a change in which atoms of substances combine or break down to produce one or more substances with different properties; also any change in the combination or breaking down of atoms in a molecule, 72

chemical test, a means of identifying the chemical properties of substances, thus making it possible to classify them, 65

chlorophyll (klôr′e·fil), the substance in green plants that is basic to photosynthesis, 233

chloroplast (klô·r′ə·plast), a tiny green body in most green plant cells, 160

chromosome (krō′mə·som), a structure inside a cell nucleus, containing a substance that is basic to determining the characteristics of each new organism, 173

cilia (sil′ē·ə), tiny hairlike structures that enable certain single-celled animals to move about or to obtain food, 169; also on certain covering cells lining the body, as on the tubes to the lungs, 201

circulatory (sûr′kyə·la·tôr′ē) **system,** the organs that work together to carry (circulate) the blood to and from body cells; the heart and blood vessels, 211

classify, to group objects by their likenesses, 63

compound, any substance consisting of two or more kinds of atoms chemically combined, 56

contract (kən·trakt′), to change in such a way that less space is occupied

core, the central part of the Earth, 21

covering cells, the outer cells of a many-celled organism or of organs inside the organism, 201

crater (krā′tər), the opening at the top of a volcano through which lava may flow if the volcano is active, 26

crest, the top point of a wave, 282

crust, the firm outer layer of the earth, averaging about 30 miles thick, 19

crystal (kris′təl), a solid formed in one of several regular shapes, usually a mineral solid, 37

cytoplasm (sī′tə·plaz′əm), in living cells, all matter except the nucleus and all membrane; in plants, chloroplasts and cell wall, as well, are not part of the cytoplasm, 153

diameter (dī·am′ə·tər), the distance from one side of a circle or sphere through its center to the other side

diaphragm (dī′ə·fram), a sheet of muscle below the lungs that, by expanding and contracting, enables the lungs to obtain oxygen from the air and return carbon dioxide (a work of the cell energy process) to it, 209

diffuse (di·fyo͞oz′), to mix or spread evenly throughout; to pass through a membrane, 157; the spreading of one substance evenly through another is **diffusion**

digestion (di·jes′chən), the breaking down in the body of complex food compounds that do not pass through a membrane into other compounds that do, 198

digestive system, all the organs that work together to break down food substances for use by body cells, 207

dissolve (di·zolv′), to mix one substance thoroughly in another substance, as sugar in water

DNA, the substance in chromosomes that is basic to determining the characteristics of an organism, 174

earthquake belts, areas around the earth where earthquakes occur frequently, 24

earthquake wave, a regular wavelike motion transmitted through the Earth in all directions as a result of slipping of rock layers in one region, 19

electron (i·lek′tron), a charged part of an atom that moves about the nucleus; electrons moving through a wire make up an electric current, 285

element (el′ə·mənt), a substance whose molecules consist of only one kind of atom, 54

ellipse (i·lips′), a closed curve flatter on two opposite sides and rounder on opposite ends, 116

energy (en′ər·jē), the ability to do work, the ability to set an object in motion

energy cycle, a continuous process in which energy is built up or stored, released, and built up again in a living cell; supplying of energy to build up ATP and the breaking down of ATP to yield energy, 152

environment (in·vīr′rən·mənt), the total surroundings of an organism, 221

enzyme (en′zīm), one of a group of substances made by cells in the body; certain enzymes (as pepsin, for instance) speed up digestion without themselves being changed permanently, 198

erosion (i·rō′zhən), wearing away of the Earth's surface by water and wind, 6

excretion (iks·krē′shən), the getting rid of wastes by the body, 218

excretory (eks′krə·tôr′ē) **system,** all the organs that work together to excrete wastes from the body, 219

exhale, to breathe out, 73

expand, to change in such a way that more space is occupied

fat, a compound of hydrogen, carbon, and oxygen, existing as a molecule; fat molecules have many more hydrogen than oxygen atoms, 182

fault, a break across layers of the Earth's crust, 33

fish, a vertebrate with scales and fins, adapted to live in water, 319

fission (fish′ən), the splitting of the nucleus of an atom, 28; reproduction by division of a cell into two cells that are alike, as in paramecium, 173

fluid (flo͞o′id), any substance that can flow

focus (fō′kəs), the place at which rays of light passing through a lens or reflecting from a mirror come to a point, 273

fold, a wavelike bend in rock layers of the Earth's crust, 33

force, any push or pull acting on an object, 93

fossil, the preserved remains or a print of a plant or animal that lived long ago, 14

fungus (fung′gəs), *plural* **fungi** (fun′ji), colorless plant that cannot make its own food but gets it from other organisms or their remains

fusion (fyo͞o′zhən), the joining of atoms of one element to form atoms of another element; some of the mass is changed to energy, 291

galaxy (gal′ək·sē), a family of millions of stars in space revolving around a center, 129

gas, a state of matter in which a substance expands to occupy a space in which it is free to move

gill (gil), the organ in the fish that separates dissolved oxygen from water, 321

gland, one of many structures that make special substances the body needs, 207

glucose (glo͞o′kōs), a sugar; when glucose is oxidized in a cell, it yields energy to build up ATP from ADP, 151

gravitation (grav′ə·tā′shən), a force that attracts all objects (masses) in the universe to one another; each mass tends to pull every other mass towards itself, 93

hemoglobin (hē′mə·glō′bin), an iron compound in a red blood cell that enables the cell to carry oxygen to other cells in the body, 205

hypothesis (hī·poth′ə·sis), a possible explanation of an object or event, which must be tested, 230

igneous (ig′nē·əs), formed by fire or heat, as certain kinds of rocks, 36

image, likeness of an object, as seen on a screen or reflected from a mirror, 273

inactive, describes an element that does not combine readily with other elements, 78

inertia (in·ûr′shə), the tendency of a body at rest to remain at rest, or in motion to remain in motion, 107

infrared light, invisible band of light next to red in the visible spectrum, 279

inhale, to breathe in, 73

interdependent (in·tər·di·pen′dənt), depending upon one another, 245

invertebrate (in·vûr′tə·brit), an animal without a backbone, 318

joint (joint), any place where two different bones are joined, usually permitting motion, 217

lava (lä′və), molten rock from within the Earth flowing from a volcano, 26

lichen (lī′kən), a double plant consisting of a fungus and a green plant, able to live on bare rock, 8

life activity, an activity necessary for the life of an organism, 221

ligament (lig′ə·mənt), a band of fiber-like cells that joins one bone to another, 203

light-year, the distance light travels in one year, 296

liquid (liq′wid), a state of matter in which a substance takes the shape of the part of the container into which it is placed

litmus (lit′məs) **paper,** a special paper used as a chemical test for acids or bases, 65

magma (mag′mə), melted rock within the earth's mantle, 31

mammal, a warmblooded animal having hair or fur, whose young is fed milk made by the mother, 330

mantle, layer of rock about 1,800 miles thick, beginning below the earth's crust, 21

many-celled, consisting of many cells organized to carry on the life activities of an organism, 167

mass, the amount of matter in an object, 96

matter, all substances of the Earth or space, or any part of them; any object that has weight or takes up space

medulla (mə·dul′ə), the part of the brain that controls breathing and heartbeat, 218

mercuric oxide (mer·kyo͝or'ik ok'sīd), a compound of mercury and oxygen, 55

metamorphic (met'ə·môr'fik), changed in form, refers to rock changed by heat within the Earth, 41

microscope (mī'krə·skōp), an instrument that magnifies very small and usually invisible objects, making them appear larger, and therefore visible to the eye

mineral (min'ər·əl), element or compound in the Earth's soil, water, or rocks, 36; also a salt of a metal such as sodium, calcium, or phosphorus as in protoplasm, 184

model, an example, or a reconstruction of an object that enables a person to explain or understand that object or a process connected with it

molecule (mol'ə·kyo͝ol), the smallest particle of a substance that still has the properties of that substance, 52

motor nerve, a nerve that carries impulses ("messages") from the brain or spinal cord to other parts of the body, 218

muscle cell, a cell that is able to shorten and lengthen, thus producing movement, 201

muscular (mus'kyə·lər), system, all the muscles in the body, 215

nerve, a bundle of neurons bound together and carrying messages from and to parts of the body

nervous system, all the organs that together keep an organism in touch with its environment and enable it to react, 218

neuron (no͝or'on), a cell that carries impulses ("messages") from one part of the body to another; also known as a nerve cell, 203

neutral (no͞o'trəl), having the properties of neither acid nor base; the color of litmus paper in a neutral substance will not change, 70

neutron (no͞o'tron), one of the particles in the nucleus of an atom, 27

nucleus (no͞o'klē·əs), the central part of an atom, 27; the central part of a living cell, 153

orbit, the curving path that a moving body takes around another body in space, 107

organ, a part that carries on a special function within an organism, 176

organism, any complete living plant or animal, 171

organ system, a group of organs working together as a main function of the organism, as in digestion, 206

oxidation (ok'sə·dā'shən), the combining of a substance with oxygen, 74

oxide (ok'sīd), a compound of oxygen and another element, 62

photon (fō'ton), a particle of light, according to one theory, 285

photosynthesis (fō'tō·sin'thə·sis), the process by which green plants use light energy in making carbohydrates, 233

physical change, a change in the form of a substance without a change in its chemical properties, 86

planet, Earth or any of the other eight bodies of matter that revolve around the Sun

prism (priz'əm), a device, such as a triangle of glass, which spreads light into a band of colors, 277

property, any characteristic that is generally true for a substance, and for which it can be tested, 52

protein (prō′tē·in), a compound of carbon, hydrogen, oxygen, and nitrogen and usually phosphorus and sulfur, existing as a molecule, 182

proton, one of the particles in the nucleus of an atom, 27

protoplanets (prō′tə·plan′its), first bodies of matter from which the planets formed (according to one theory), 114

protoplasm, all the living substances in a cell, 182

protozoa (prō′tə·zō′a), single-celled animals, 171

radioactivity, the slow breaking up of the nucleus of an atom; any element whose nucleus is breaking up is **radioactive,** 28

reaction (rē·ak′shən), a force acting in a direction opposite to that of another force (action), 104. *See also* **chemical reaction**

red blood cell, a cell in the blood able to carry oxygen to other body cells, 205

reflected, bounced off an object, with a change of direction, as light from a mirror, 276

reproduce (rē′prə·do͞os′), to produce another cell like itself, or another organism like the parent organisms, 146

reptile (rep′til), a cold-blooded animal with scales and laying soft-shelled eggs; it breathes by means of lungs, 309

respiratory (ri·spīr′ə·tôr′ē) **system,** all the organs used in breathing, 209

revolution (rev′ə·lo͞o′shən), the motion of one body in space around another, as the Earth around the Sun, 112

root hair, a hairlike cell of plant roots through which water and dissolved minerals from the soil enter a plant, 161

rotation (rō·tā′shən), the turning of a body around an imaginary line drawn through its center, 112

saliva (sə·lī′və), a digestive fluid made by glands in the mouth, 196

salivary (sal′ə·ver′ē) gland, a gland in the mouth that makes saliva, 208

satellite (sat′ə·līt), a natural object, such as the Moon, or a man-made object that revolves about a body in space, 111

sediment (sed′ə·mənt), particles of rock, soil, and other substances that settle out from water which carries them, 13

sedimentary rock, rock formed from sediment, 14

seismograph (sīz′mə·graf), a device for recording earthquake waves, 19

sensory (sen′sər·ē) **nerve,** a nerve that carries messages from the body to the brain or spinal cord, 218

single-celled, consisting of one cell able to carry on all life activities, 167

skeletal (skel′ə·təl) **system,** all the bones that support and protect the body and to which organ systems are attached, 216

solar (sō′lər) **system,** the Sun and its planets and other bodies that revolve around it

solid (sol′id), a state of matter in which a substance keeps a definite shape

spectrum (spek′trəm), a band of colors (light of different wavelengths) that is formed when light is passed through a prism, 279

stable, characteristic of an atom whose nucleus does not break up or change, is not radioactive, 29

structure (struk'chər), the way a cell, tissue, organ, or organism is built; also the way the parts fit together in a complete organism, 161; also refers to the make-up of the atom

supporting cells, cells that give shape and support to the body, 203

tendon (ten'dən), a band of tough cells that joins bone to muscle, 203

theory (thē'ər·ē), a reasonable explanation of objects or events that seems to fit the evidence about them that has been gathered, 16

thrust, the force that gives a rocket its forward motion, 99

tissue (tish'o͞o), a group of similar cells doing one kind of work, 205

ultraviolet (ul'trə·vī'ə·lit) **light**, invisible band of light next to violet in the visible spectrum, 280

unbalanced force, a push or pull that is greater than an opposite push or pull, 100

valve (valv), a structure in the heart or veins that lets the blood flow in only one direction, 214

vein (vān), a blood vessel that carries blood from the body toward the heart, 211

ventricle (ven'trə·kəl), a part of the heart that pumps blood to the body, 213

vertebra (vûr'tə·brə), any of the small bones in the backbone which permit motion and through which the spinal cord passes, 217

vertebrate (vûr'tə·brāt), an animal with a backbone, 319

vitamin (vī'tə·min), one of many substances made by organisms and needed by cells for proper functioning, 246

volcano (vol·kā'nō), usually a mountain built up of lava, ash, and hot gases from within the Earth; a volcano begins with an opening in the Earth's crust through which these substances flow, 25. *See also* **crater**

wave, any regular back-and-forth or up-and-down motion that transmits energy through matter or through space, for example, a light wave or earthquake wave

wavelength, the distance between the top of one wave and the top of the next, 282

weathering (weth'ər·ing), breaking down of rock by heat, cold, and water, 6

weight (wāt), a measure of the force of gravitation acting on an object (a mass), 94

white blood cell, a cell in the blood that aids in destroying bacteria that have entered the body, 205

word equation, a statement in words of the substances produced by breaking down a compound chemically or of those produced by the combining of substances, 58

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